Performing seismic scenario in the Luchon-Val d'Aran area, Central Pyrenees

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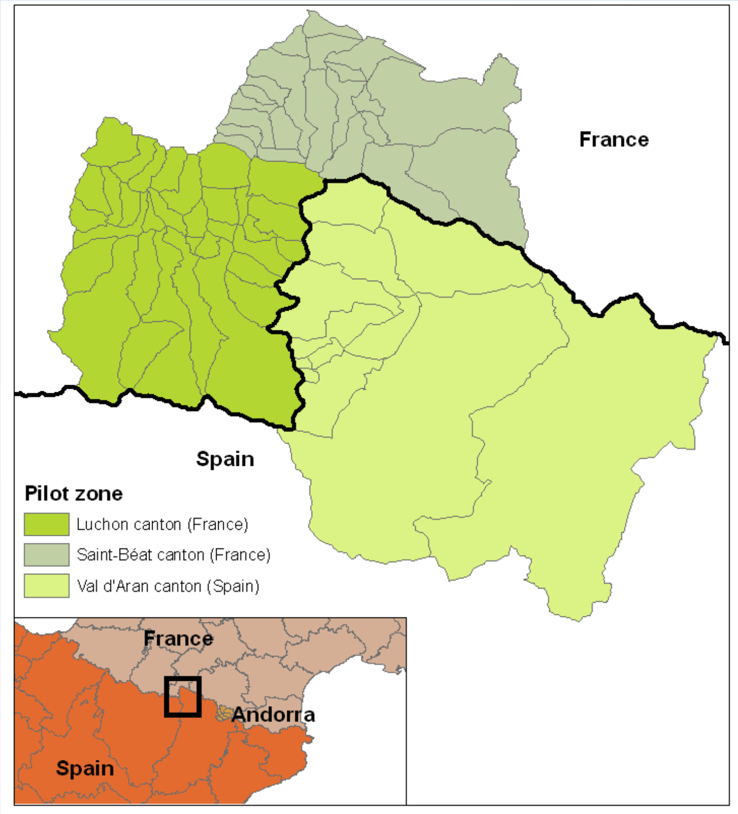
Introduction

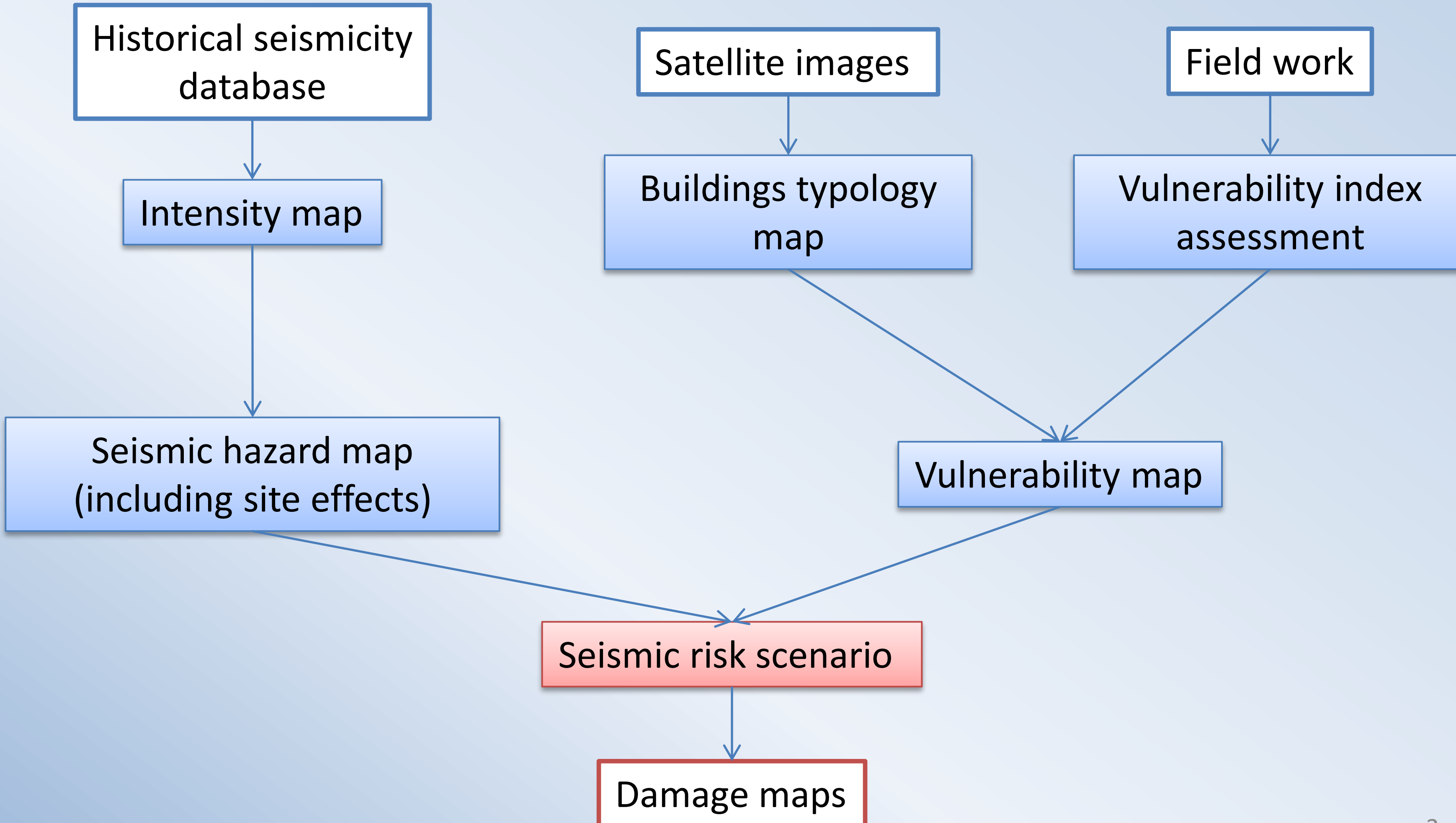
- SISPYR project
  - M1: Improvment of the realtime seismic network of Pyrenees
  - M2: Seismic data exchange (in relation to M1)
  - M3: Improvment of seismic knowledge on Pyrenees
  - M4: Seismic risk mitigation: shakemaps and risk scenarii
  - M5: Early Warning System faisability
  - M6: Communication

- Realization of 2 seismic scenarii in the pilot zone of Val d'Aran and Luchon-Saint Béat (part of the M4 module)
  - Deterministic scenario (1923 earthquake)
  - Probabilistic scenario

- Why here ?
  - Important tourist zone within the Pyrenees. Ski resorts (Baqueira Beret, Superbagnères) and thermal (Bagnères de Luchon).
  - One of the most active zone of France and Spain in terms de seismicity
    - M 4.8 in Lège (France) in 1999
    - Vielha earthquake in 1923. Intensity VIII-VII.

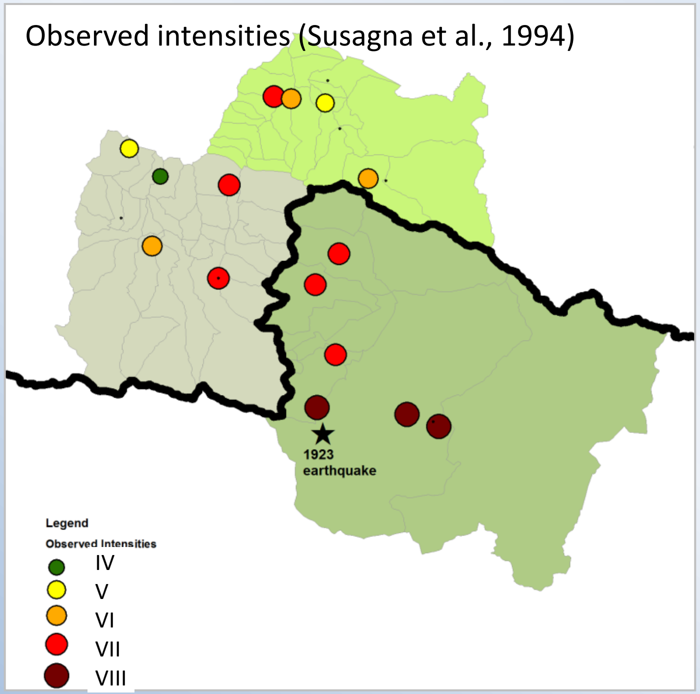


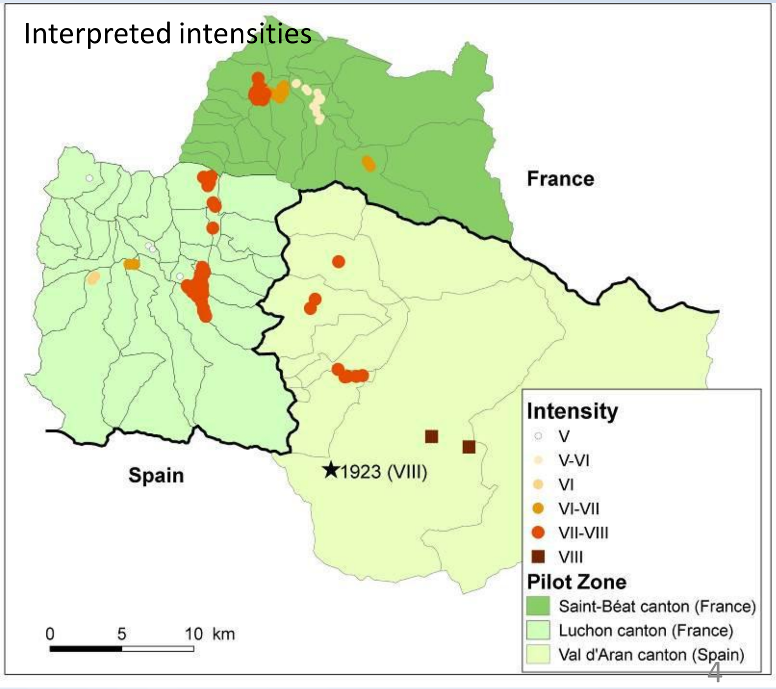
Deterministic scenario scheme



Deterministic scenario: seismic hazard map

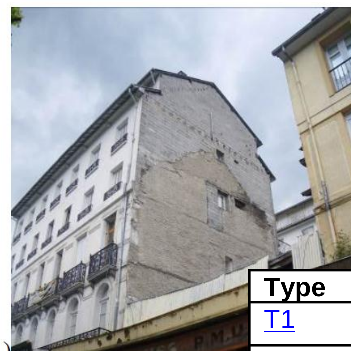
- Based on observed and interpreted intensities from 1923 earthquake
- Epicenter south of Vielha
- In Vielha downtown intensity VIII
- Intensities between VII (valleys) and V

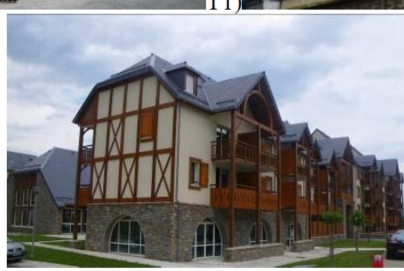




Deterministic scenario: vulnerability index assessment

- Identification of the main building types within the zone
- Identification of the main vulnerability factors
- Association to RISK-UE types (vulnerability index)

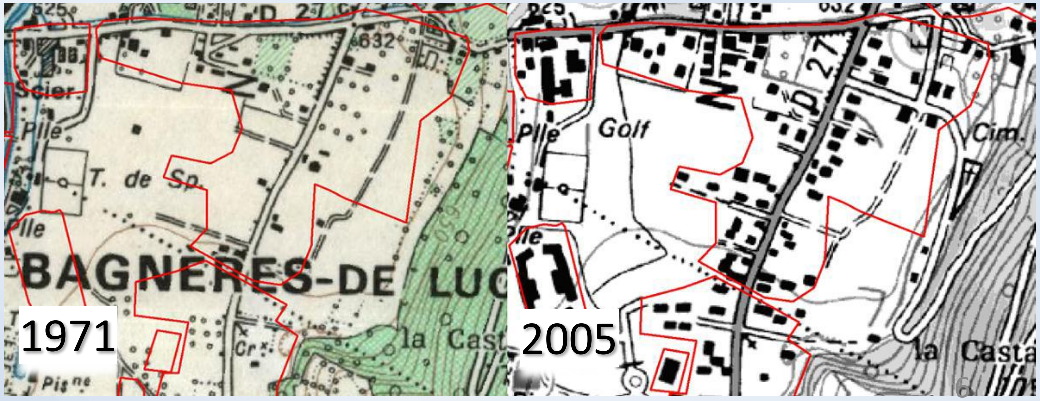




Type	Structure	RISK-UE type	Description
T1	Bearing walls in stone masonry	M1.2	Traditional housing.
T1'		M1.2-M1.3	Big buildings from Bagneres de Luchon.
T2	Unrenforced masonry	M3.3	Unreinforced masonry. Composite slabs.
T3		M3.4	Unreinforced masonry. RC slabs.
T4	RC structures	RC3.2	RC frames and masonry infill walls. Structure with irregularities.
T5		RC2	RC shear walls.
T6	Steel structures	S3	Steel structure with masonry infill walls
T7	Wooden structures	W	Chalet

Deterministic scenario: buildings typology map

- Estimation based on
  - Interpretation of aerial images
  - Using census data
  - Field work
  - Interview with local constructors and architects
- Mapping of built homogeneous zones
  - Downtown
  - Disseminated areas
  - Housing state
  - Flats

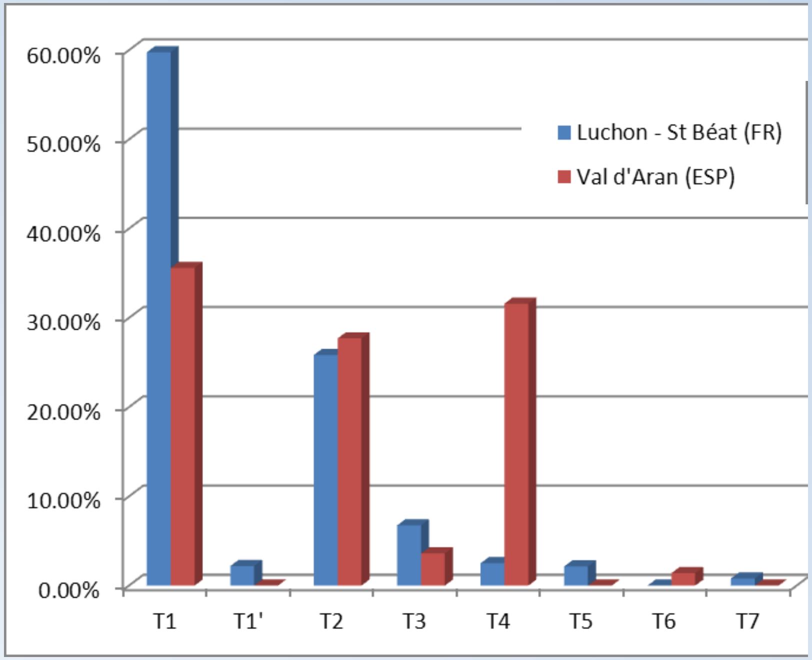


Deterministic scenario: vulnerability maps

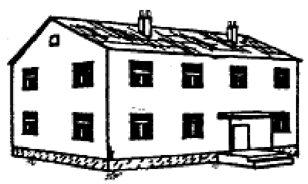
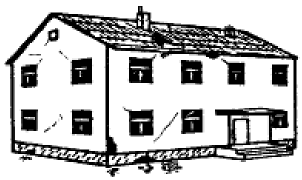
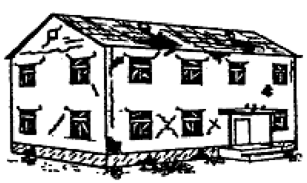
- French side: big urban development at XIX century and XX (thermal tourism in Bagneres).
  - T1 and T1’ are the main types

- French side, low development during the 1970-80s

- Val d’Aran: important development in the 1970s (ski resorts).
  - high number of collective dwelling buildings (T4)



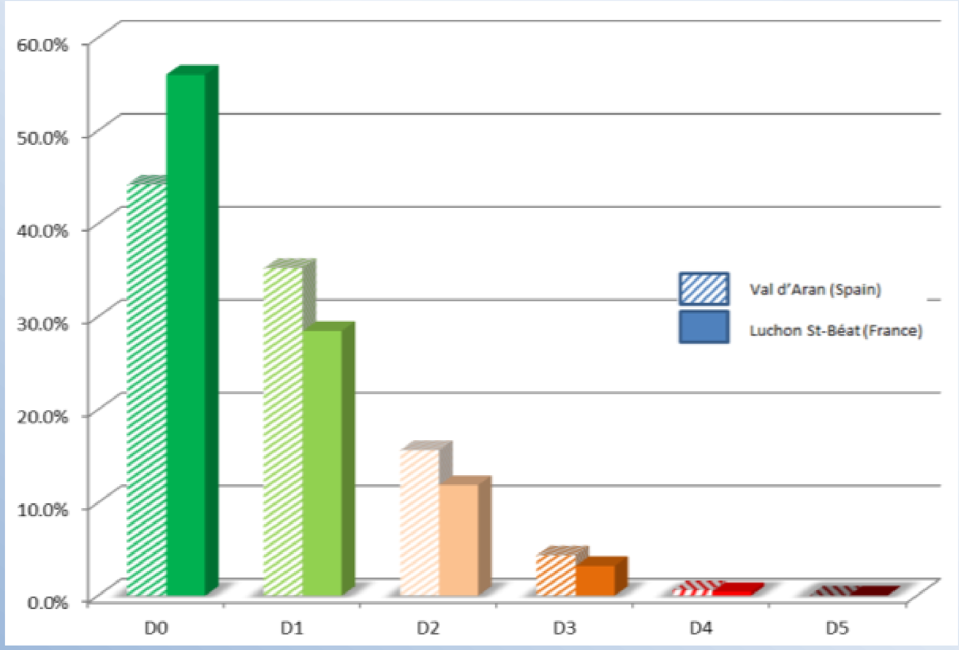
Deterministic scenario: damage calculations

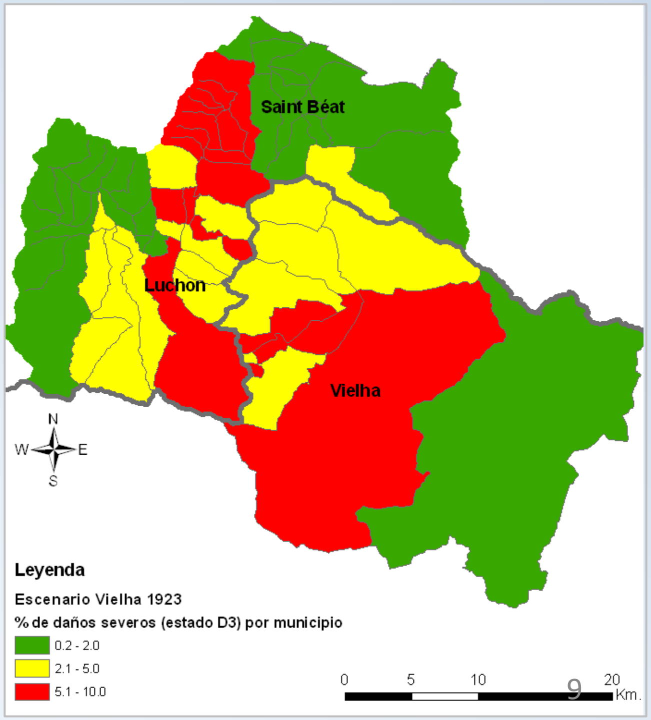
Classification of damage to masonry buildings	
	**Grade 1: Negligible to slight damage** **(no structural damage, slight non-structural damage)** Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
	**Grade 2: Moderate damage** **(slight structural damage, moderate non-structural damage)** Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage, heavy non-structural damage)** Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
	**Grade 4: Very heavy damage** **(heavy structural damage, very heavy non-structural damage)** Serious failure of walls; partial structural failure of roofs and floors.
	**Grade 5: Destruction** **(very heavy structural damage)** Total or near total collapse.

Photos from Lorca earthquake

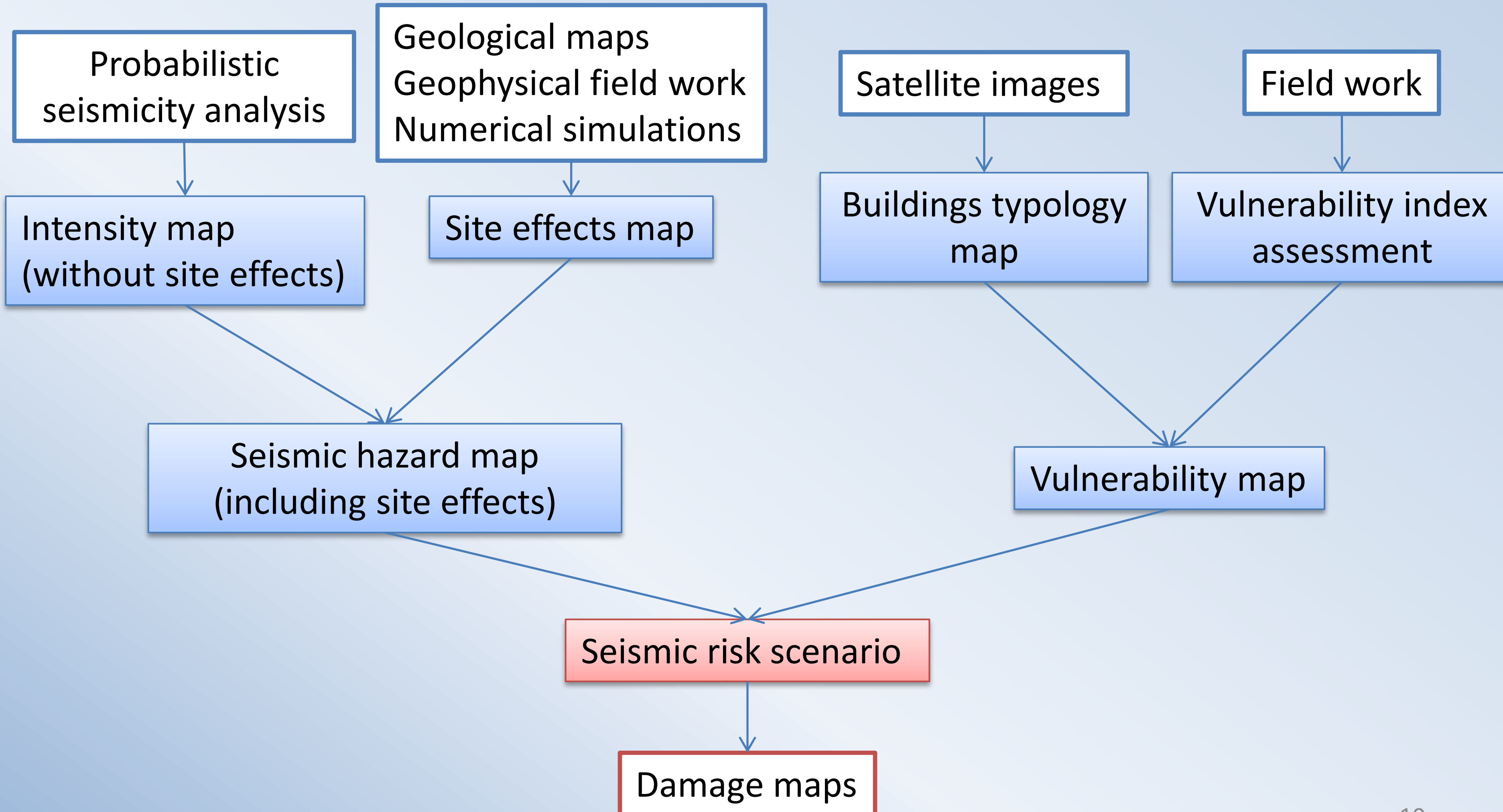
Deterministic scenario: results

- Physical damages to built environment
  - Partial collapse (D4) or complete collapse (D5) minor to 2%
  - Strong damage (D3) between 5 and 10% into the most important cities: Bagnères-de-Luchon and Vielha
  - Minor damage or no damage for the majority of buildings



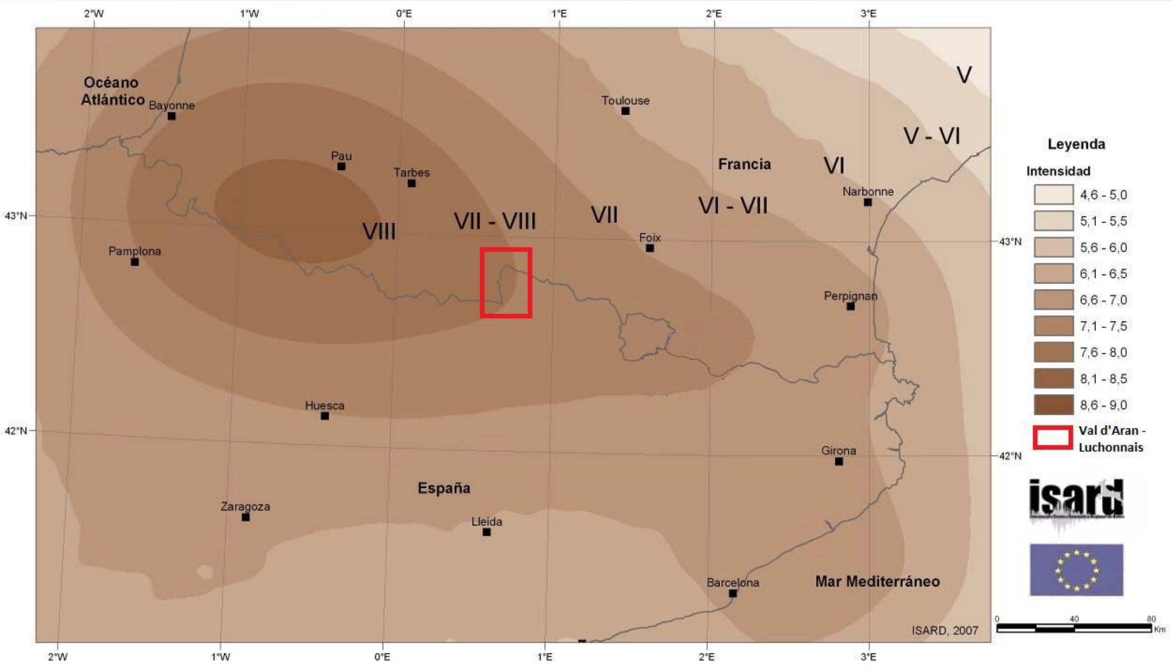


Probabilistic scenario scheme



Probabilistic scenario: intensity map

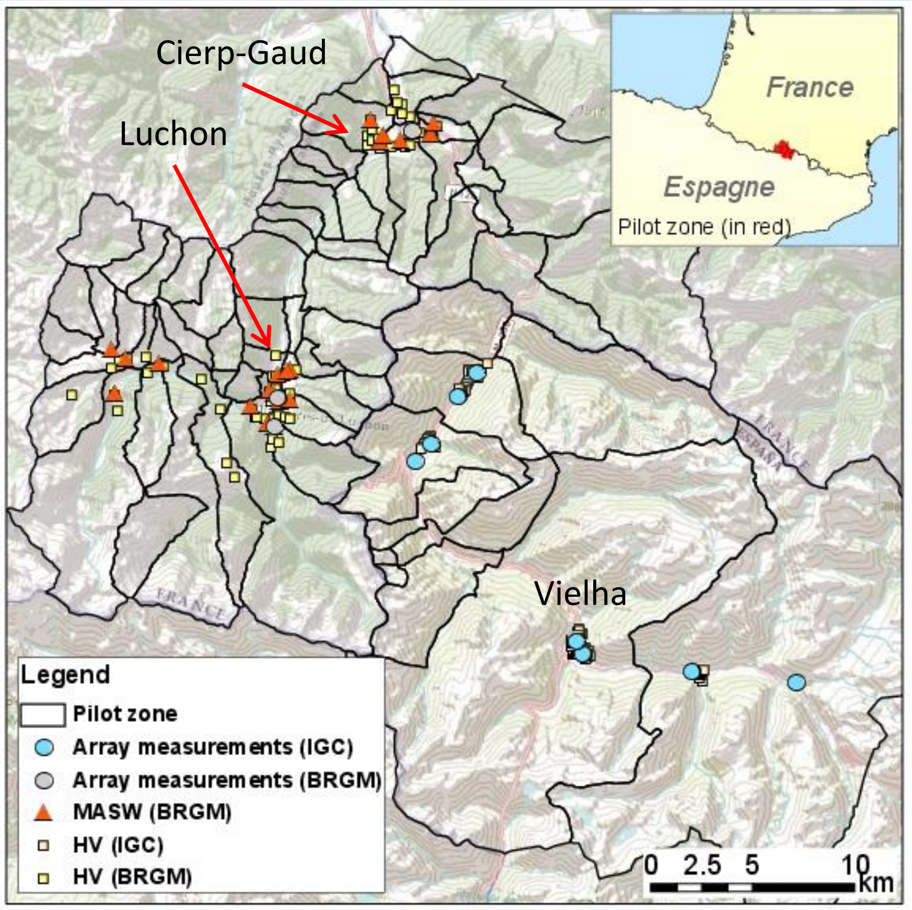
- Intensity map derived from previous works on Pyrenees (ISARD project, 2006) (return period: 475 years)



- Intensity used on the whole pilot zone: VII-VIII

Probabilistic scenario: site effects assessment

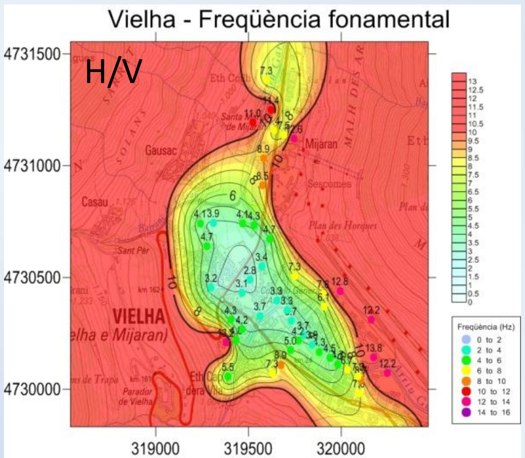
- Analysis based on:
  - Geological maps
  - Geotechnical data (very few on the French side)
  - Geophysical data
    - H/V for site effect detection and resonance frequency measurement
    - MASW for Vs profiles (shallow depths up to 30 meters)
    - Array measurements for Vs profiles (medium depths up to 100 meters)
- Field work performed by IGC and BRGM
  - France: 75 H/V, 21 MASW, 3 arrays
  - Spain: 98 H/V, 8 arrays
- First results
  - France: low frequencies site effects (down to 0.5 Hz) interpreted as very deep deposits (more than 100 m depth) in the axial Luchon valley and the Northern site of Cierp-Gaud
  - Spain: high frequencies site effects coherent with straigth valleys and thin quaternary deposits overlying bedrock



Probabilistic scenario: site effects assessment

- Several steps:
  - Mapping of homogeneous zones in terms of geology, resonance frequency and Vs profiles
  - Estimation of a standard soil column for each zone
  - Calculation of its response under a specific excitation (acceleration spectra derived from previous work on regional seismicity, Secanell et al., 2008)
  - Translation of this response into intensity increment (EMS98 scale) (from Arias Inetnsity following Cabañas et al., 1997)

Probabilistic scenario: site effects assessment (example of Vielha)



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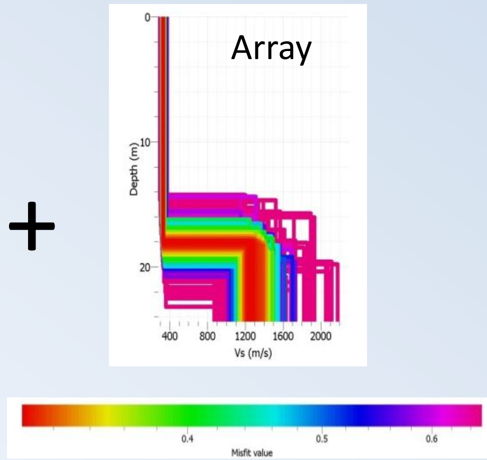
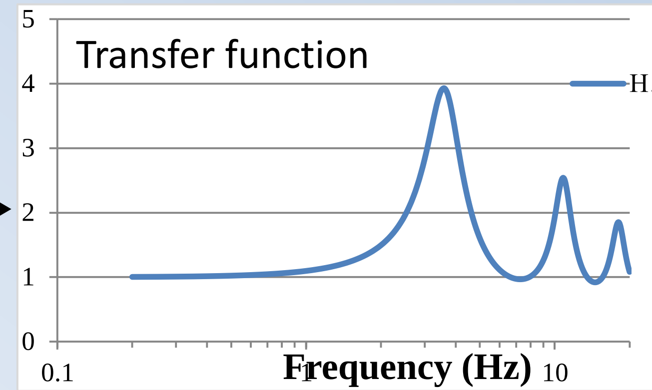
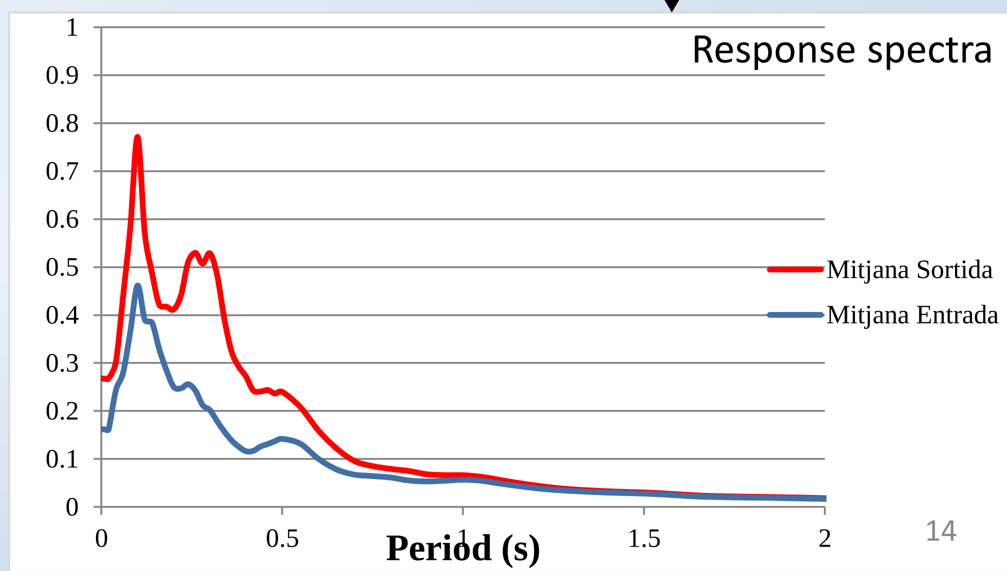
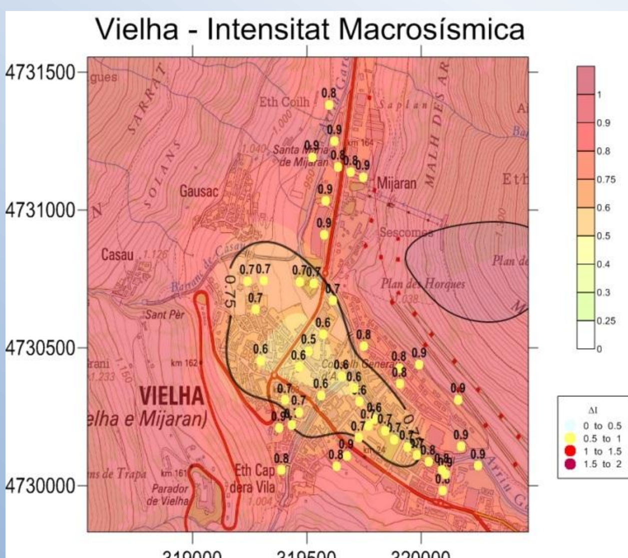


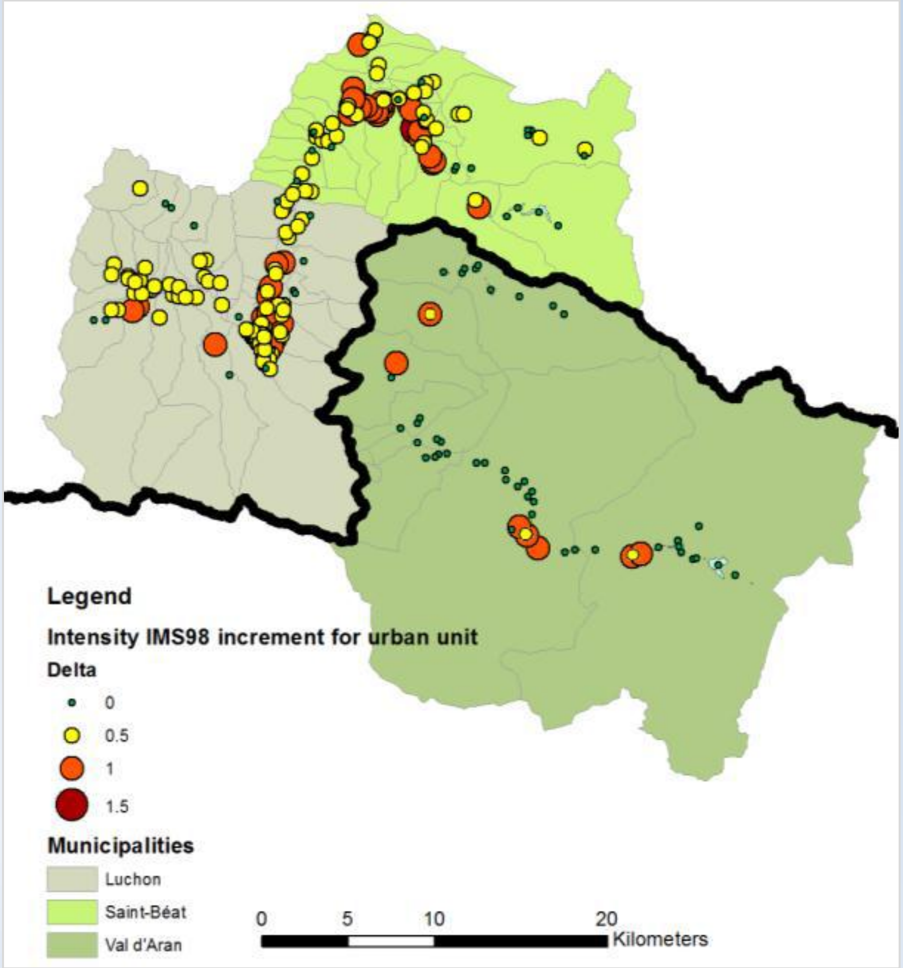






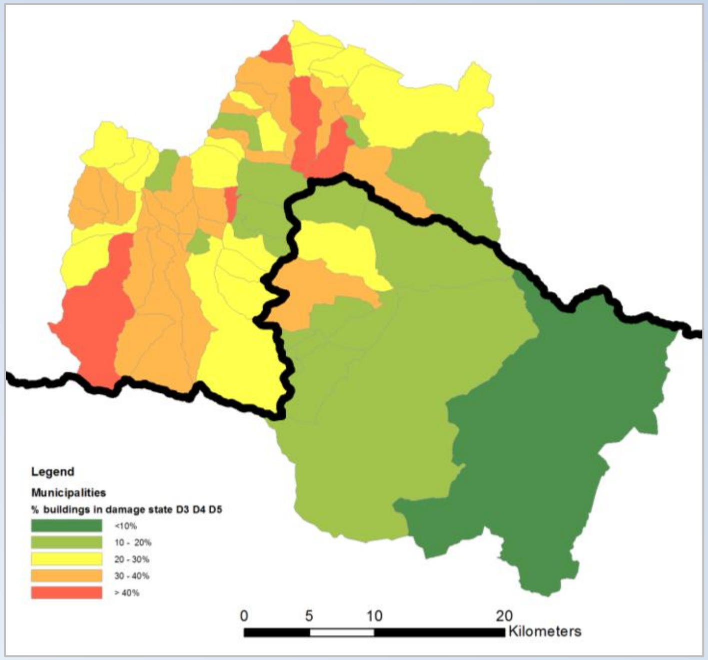
Probabilistic scenario: seismic hazard map

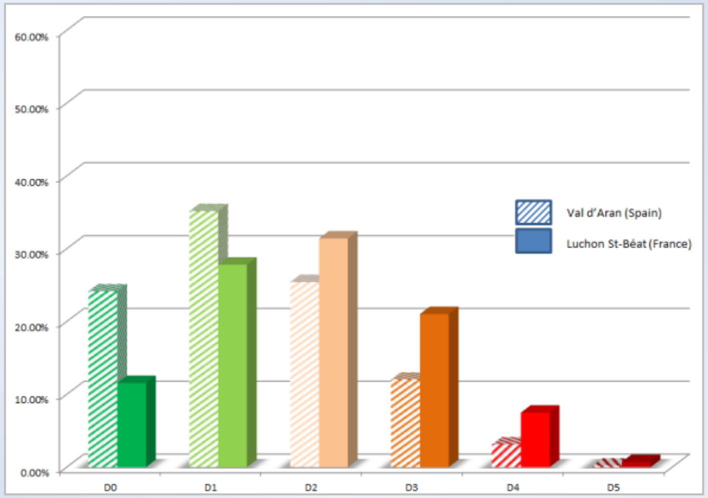
- Intensity increment calculated for each homogeneous site effects zones (with geophysical measurements)
- Extrapolation to zones without geophysical measurements (on base of geology)
- Intensity increment map on the whole pilot zone (EMS98 scale)
- Stronger site effects on the French side (larger valleys with deeper sediments deposits)



Probabilistic scenario: results

- Vulnerability: same as deterministic scenario
- Damage calculation method: same as deterministic scenario
- Physical damages to built environment:
  - Higher expected damages on French side
  - Heavy damages (D4 and D5) <10%
  - Spanish side has more built areas over bedrock zones ➔ minor damages
  - Big number of buildings on D2-D3 damage state





Conclusions

- Realization of 2 scenarii for seismic risk mitigation purposes
  - A deterministic one (1923 earthquake)
  - A probabilistic one (return period of 475 years)
  - Including:
    - Regional seismicity (regional seismic hazard)
    - Site effects (local seismic hazard)
    - Building stock vulnerability
  - Calculation and mapping of buildings damage distributions

- Deterministic scenario
  - Ratio of partial or total collapse <2%,
    ➔ reduced number of potential victims, non structural damages
  - Considerable number of buildings in D3 in downtowns as Vielha or Bagnères de Luchon
    ➔ important number of people without shelters

- Probabilistic scenario
  - Necessary to avoid bias due to wave propagation effects for damage comparison between two neighbourhood (attenuation of seismic motion when moving away from epicenter)
  - Expected damage more important into valleys (higher site effect)
  - Higher damage on French side (buildings concentration into valleys, lower number of recent buildings)
  - Lower damage in Val d'Aran (construction around ski resort more recent and on bedrock).