International Technical Meeting
''Seismic Safety of NPPs''
Tivoli (Rome, IT) - March 25-26, 2010

Seismic Hazard and site-response analyses

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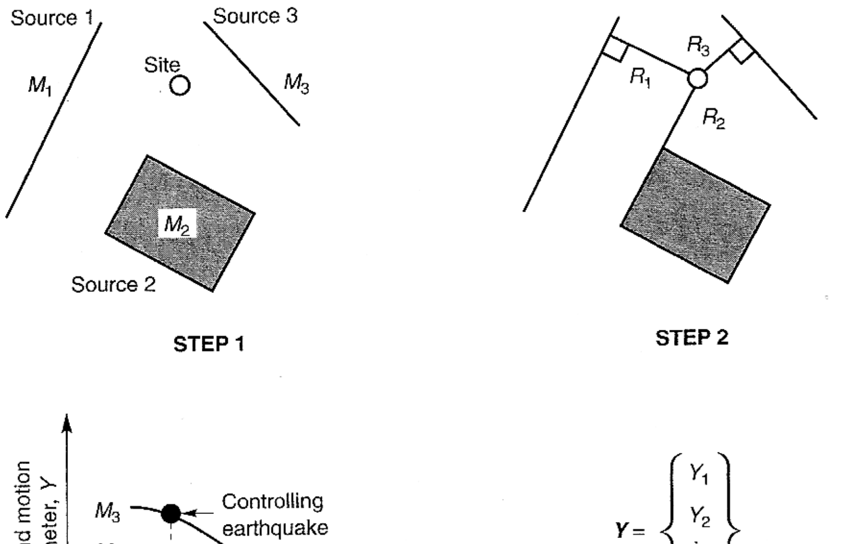
Ground Motion Hazard (1/2)

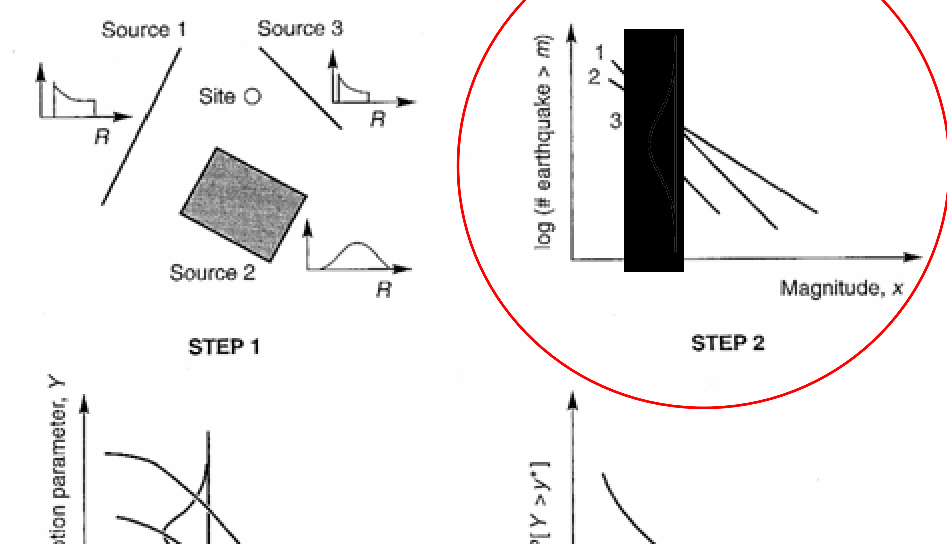
- **Most of the international regulatory guides on NPPs (US R.G. 1.165, 1997 and R.G 1.208, 2007; IAEA NS-G-3.3, 2002 and its update DS422, 2009) relies on both deterministic (DSHA) and probabilistic (PSHA) seismic hazard analyses for the design of NIs**
- **They jointly benefit from a mutual interaction since …**

Ground Motion Hazard (2/2)

- … DSHA provides a check of the reliability of PSHA at very low frequencies of exceedance (robustness of estimated GM values versus those derived from the maximum credible ones), and
- … vice versa PSHA allows selecting reference earthquakes (for deterministic analyses) within a probabilistic framework through the hazard deaggregation technique

DSHA vs. PSHA



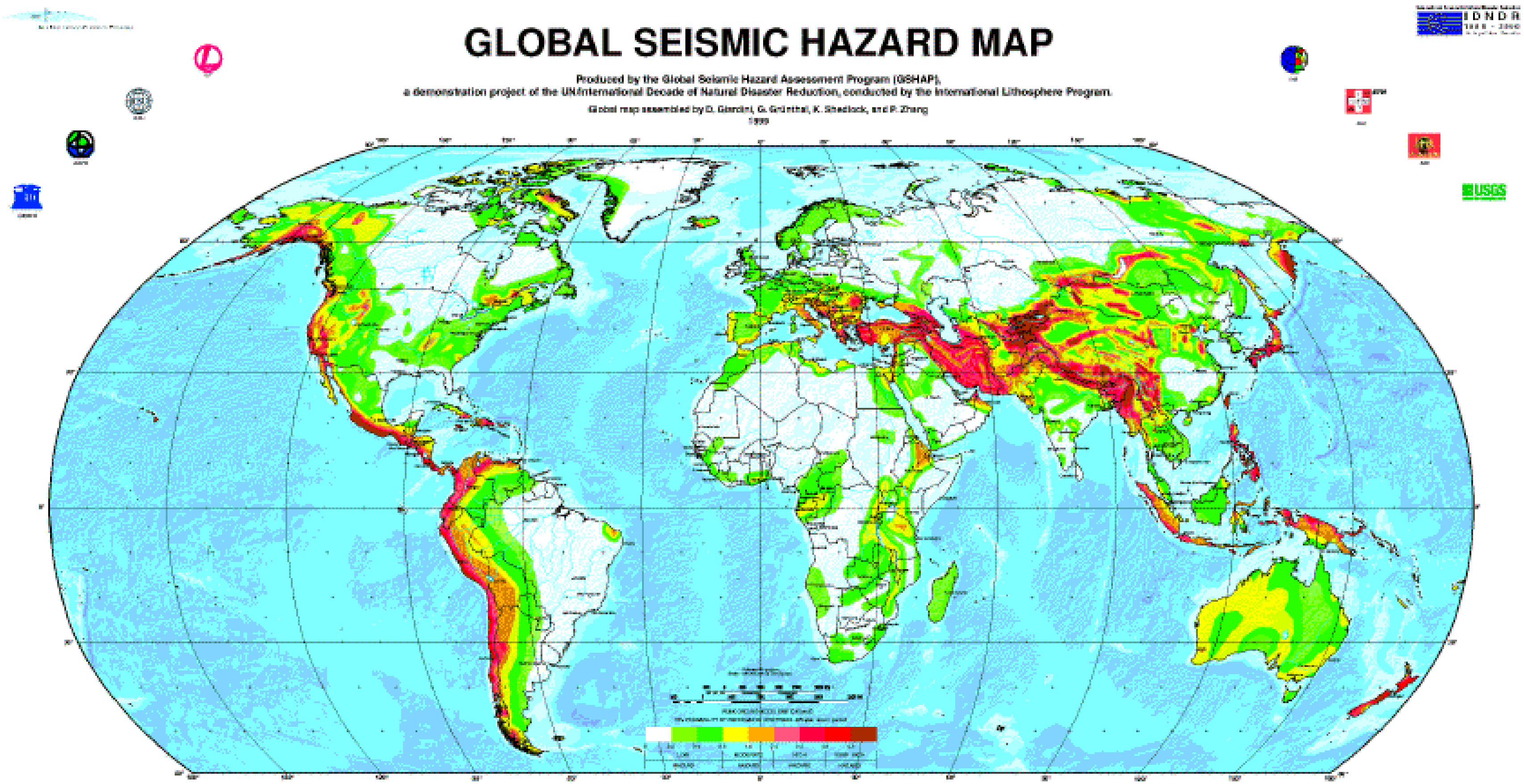


Main difference: PSHA requires determining a frequency-magnitude relation for each source

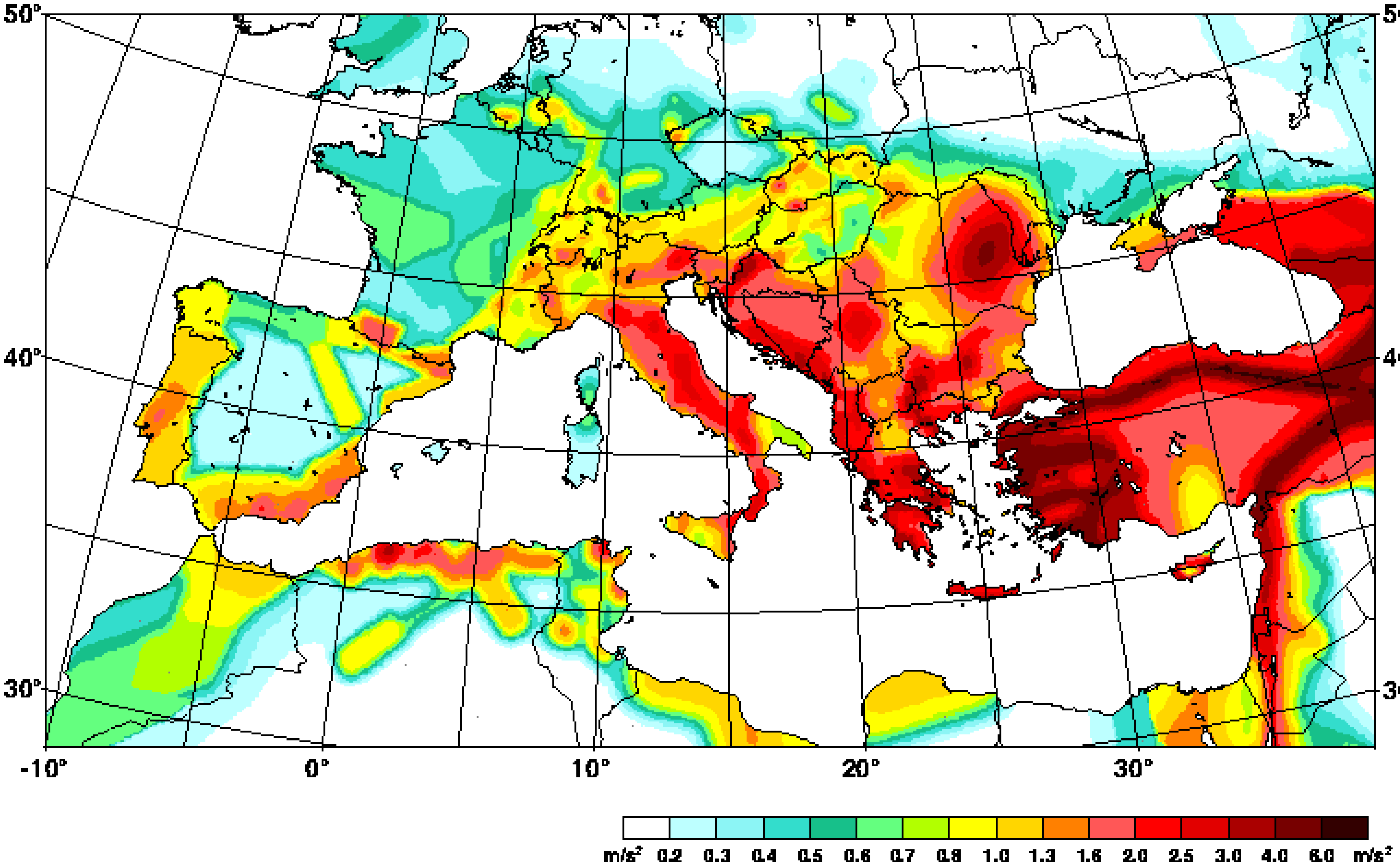
Frequency-magnitude relationships

- To assess earthquake recurrence rates a well documented (or recorded) seismicity is compulsory
- Only few countries in the world have a well documented historical seismicity (e.g., China and Italy have seismic catalogs that start since 1000 A.D. or earlier)
- Instrumental seismic catalogs may be useful only for very active regions (inter-plate regions), where the earthquake cycle is short enough to be captured by recorded seismicity

Global Seismic Hazard Assessment

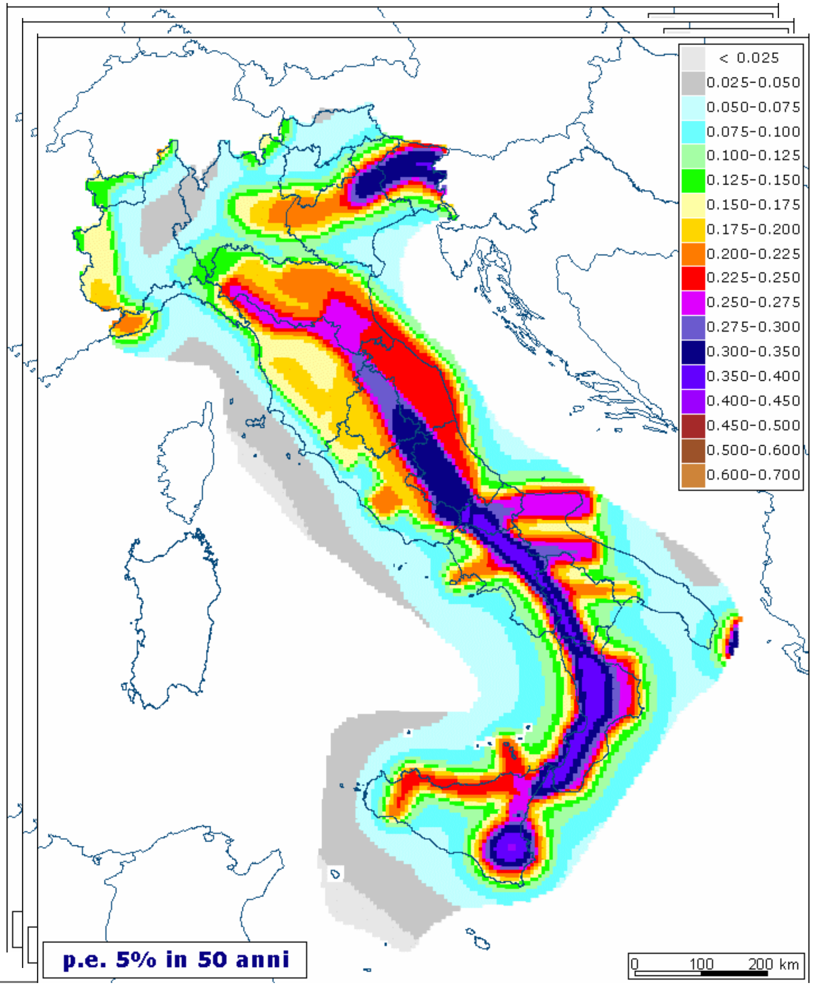


Shared information on seismicity and seismotectonics brought to integrated SH assessments



Seismic Hazard Maps

Many countries have Seismic Hazard Maps (SHMs) at different exceedance probabilities for the purpose of matching a performance-based approach in the engineering design

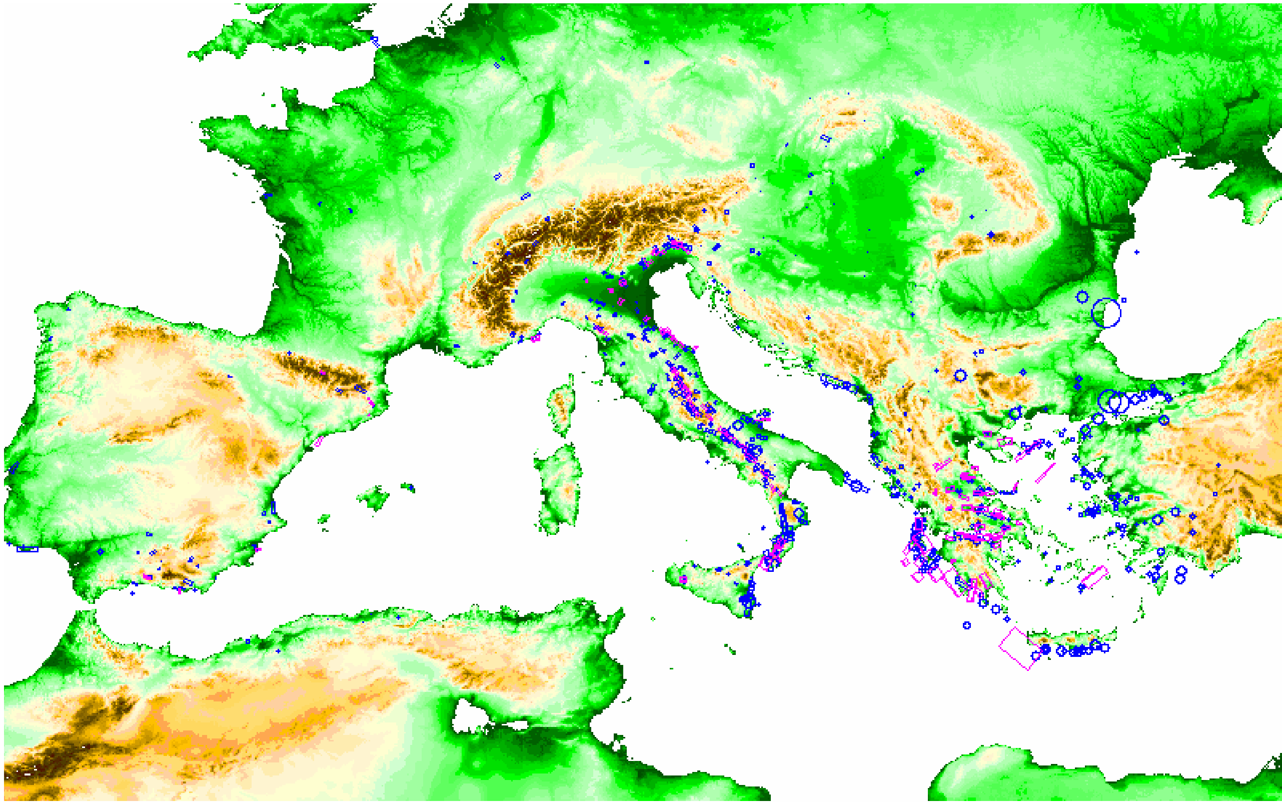


SHMs for conventional versus nuclear engineering design

- Frequencies of exceedance in conventional engineering design are in the order of [some units of] $10^{-2} \div 10^{-3}$ (ULS in common PBEED)
- In the nuclear engineering design frequencies of exceedance for SL-2 (or SSE) are in the order of $10^{-3} \div 10^{-5}$
- These lower probabilities require longer seismicity records and/or greater magnitude observations relying on the knowledge of active faults

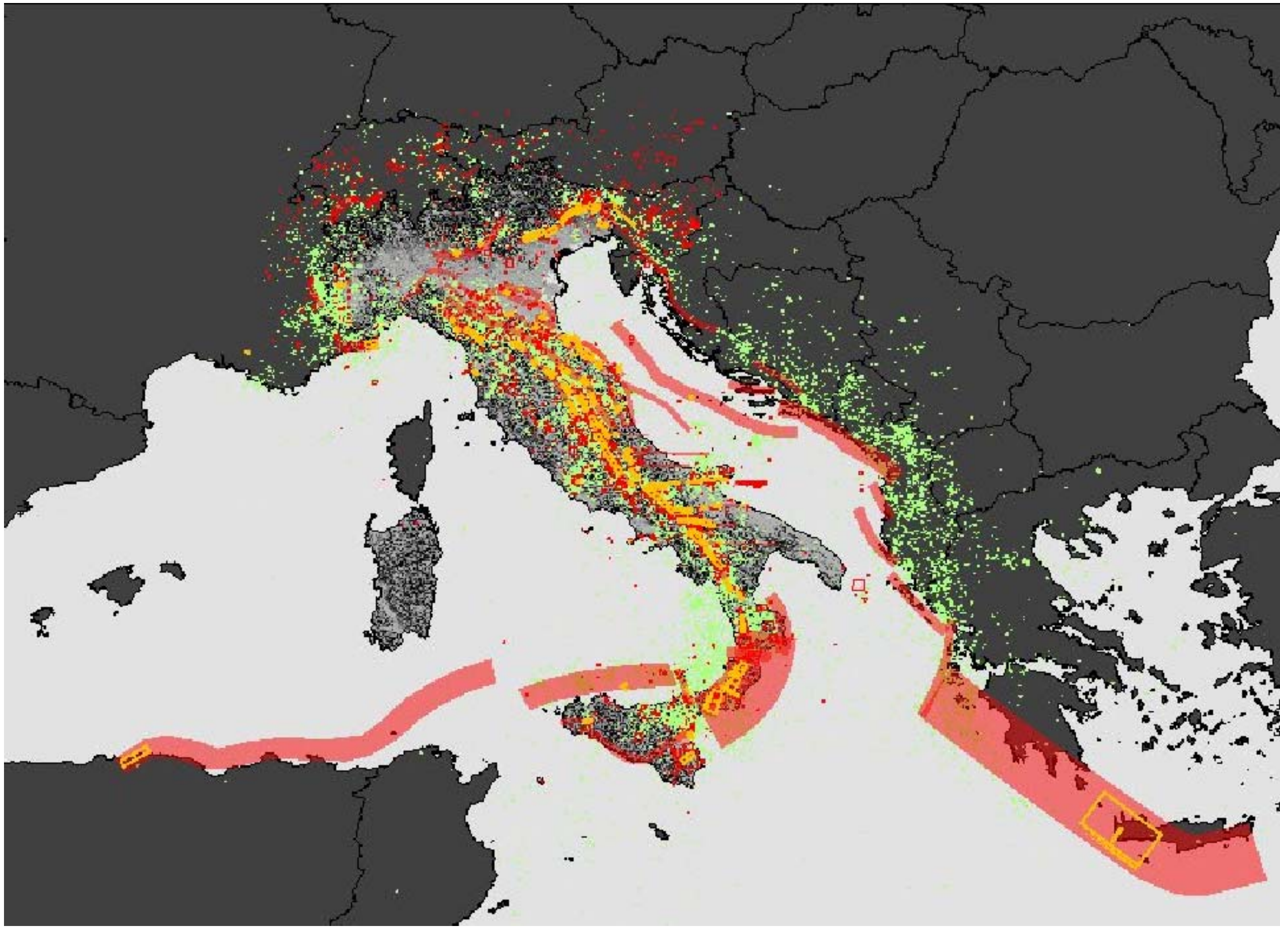
Active Faults

Improved earthquake monitoring and advances in remote sensing increase our knowledge about location of active faults



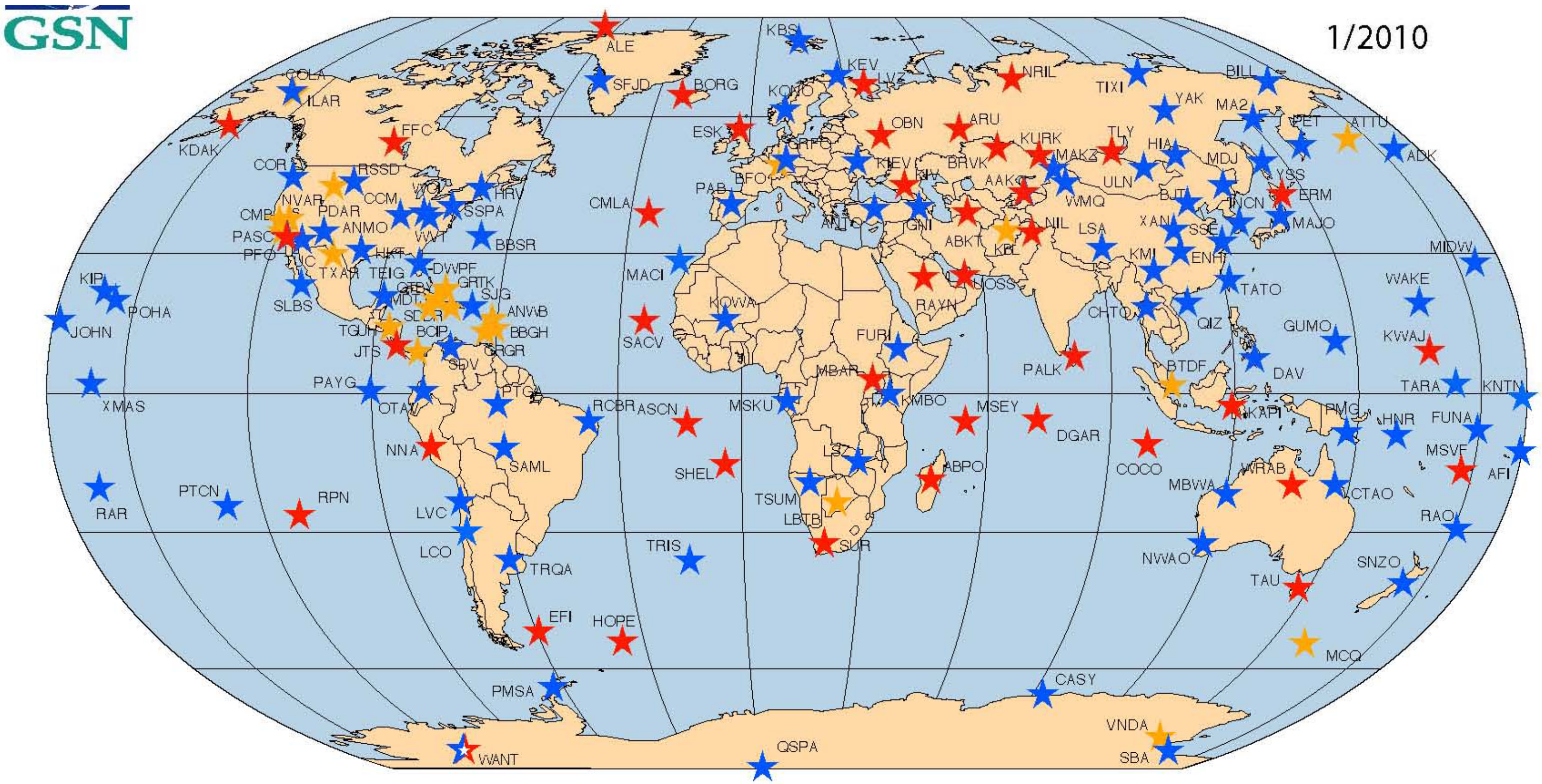
Faults and Seismicity

Faults linked to seismicity extends our capacity to investigate extreme events (at very low frequencies of exceedance)

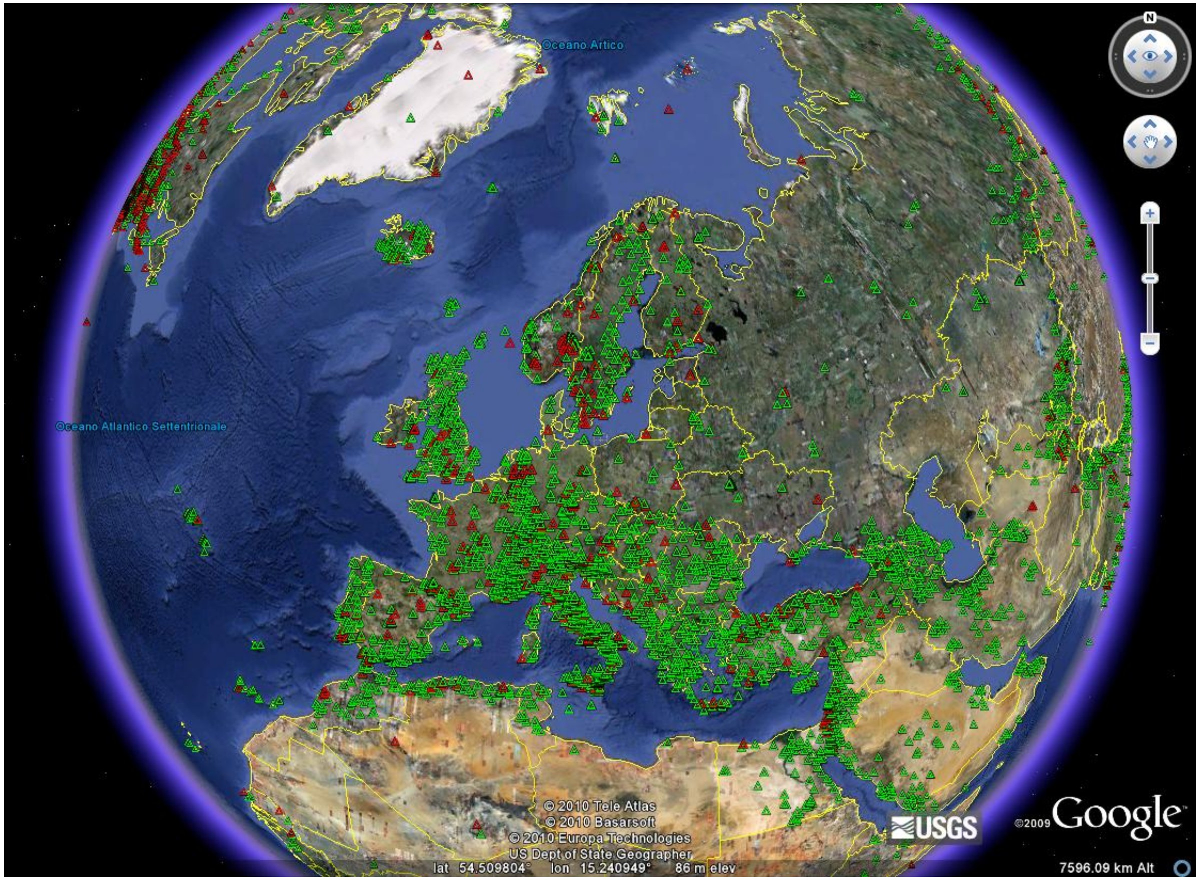


Global Seismographic Network:

started in 1990 with about 40 stations
is now over 150 stations

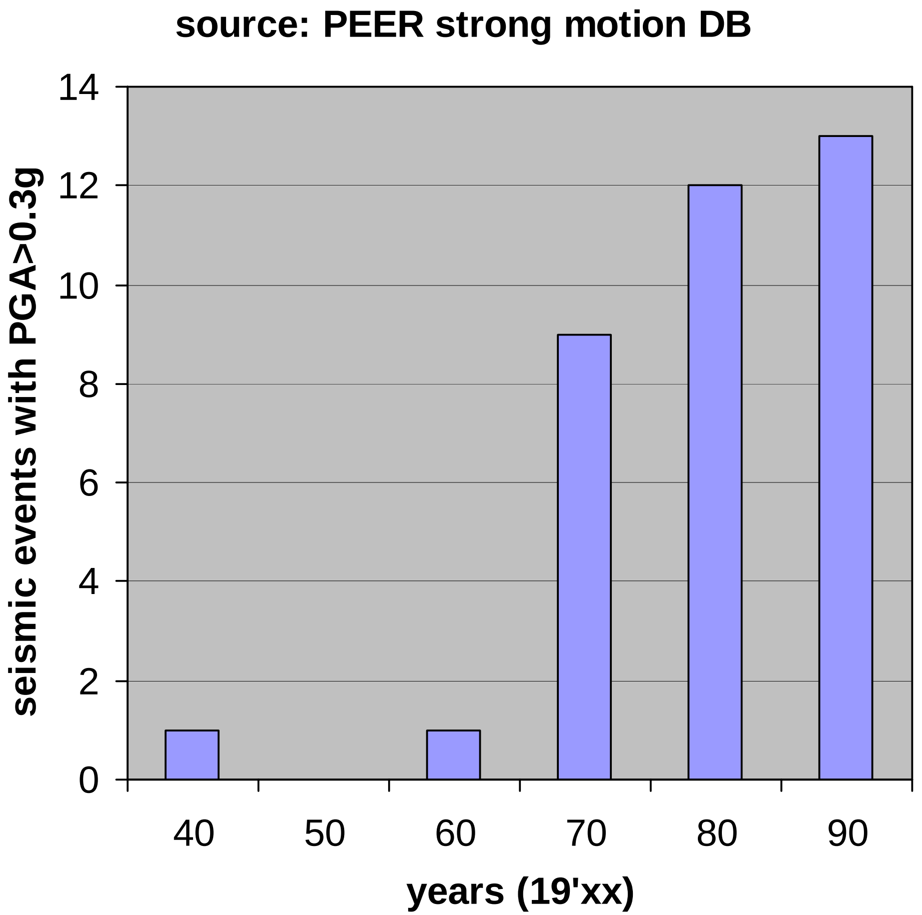


GSN is supplemented by regional and local seismic networks



Recorded Ground Motions

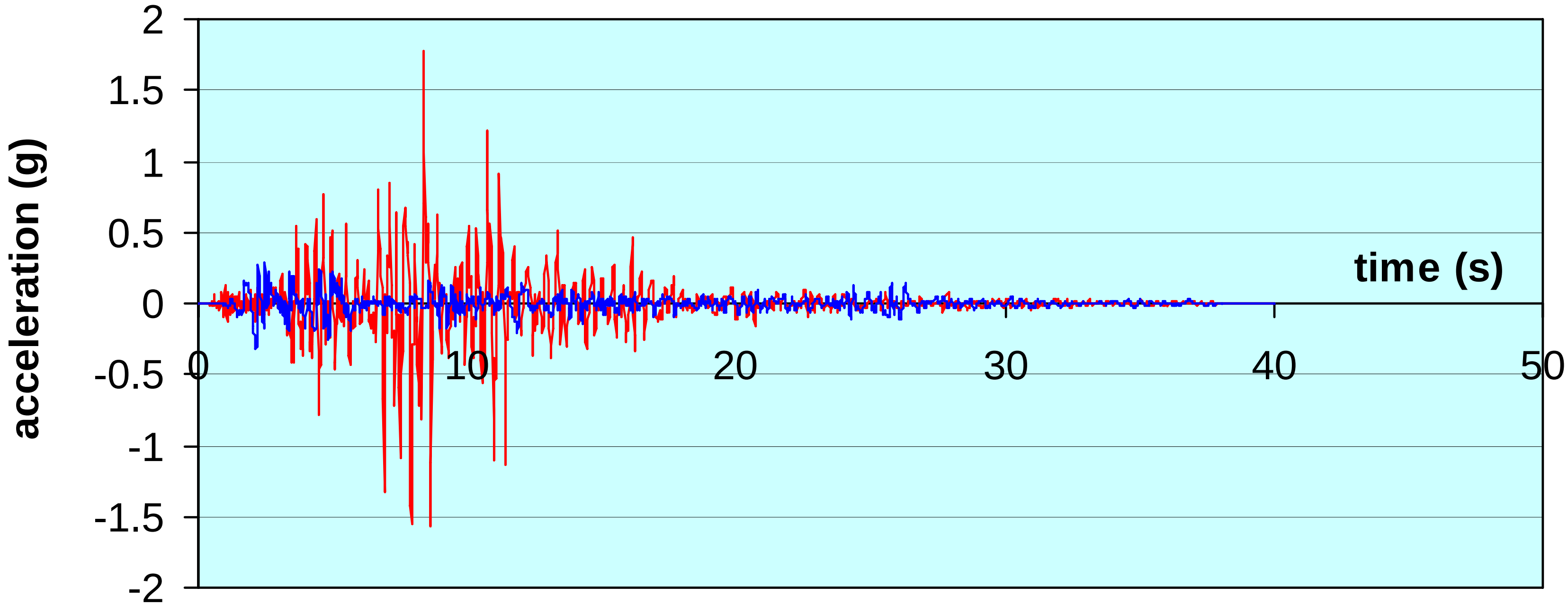
The great improvement of recording capability brought in the last decades to record a large number of strong ground motions



The perception of ground motion hazard: before 1950s…

… and after…

Cedar Hill 1.67g, R12, Vs 255 (Northridge 1994, M6.7)



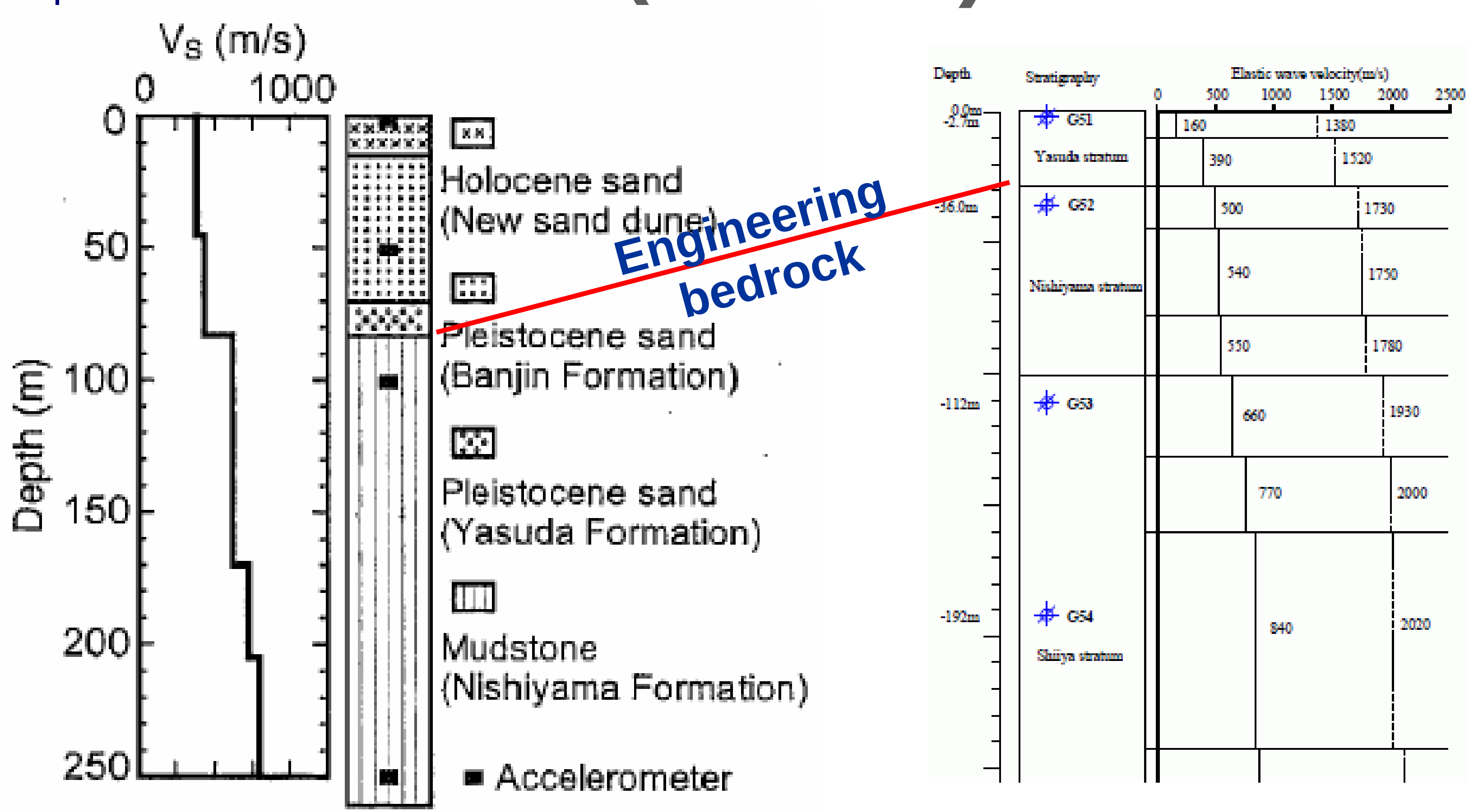
Site-response analysis

Ground Motion Hazard
PSHA ↔ DSHA

Local Seismic Response Analysis

Design Basis for Vibratory Ground Motion (SSE and OBE)

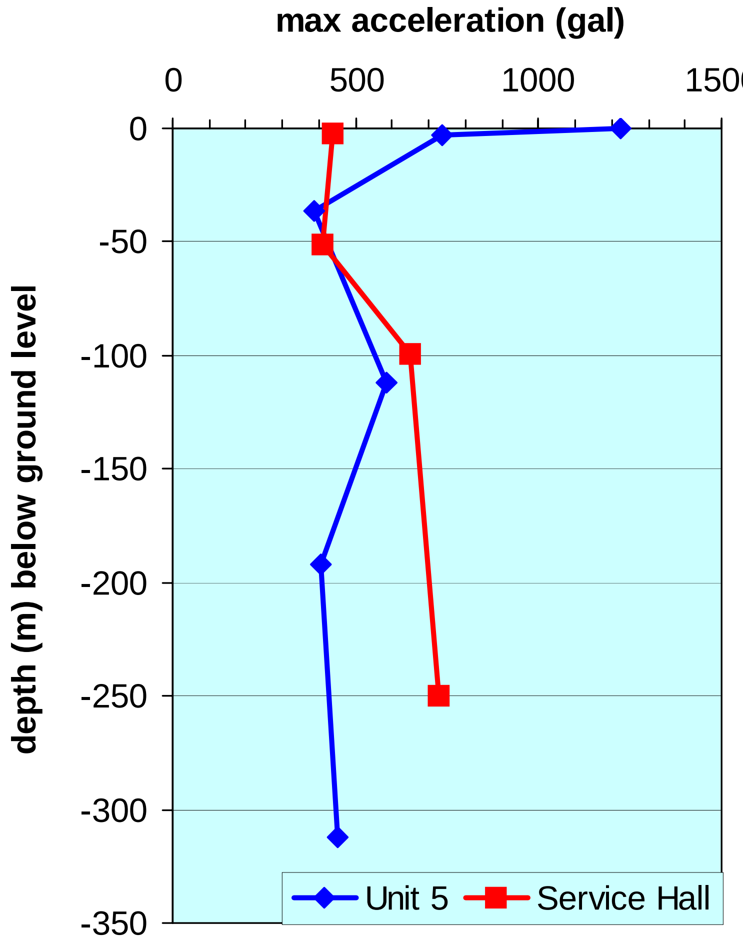
Site response evidences:
Service Hall (KK-NPP) Unit 5 R/T



Recorded accelerations in vertical arrays

Elastic soil behavior (Unit 5) increased free-field ground accelerations by a factor 3

Non-linear soil behavior (Serv. Hall) decreased ground accelerations by a factor 2



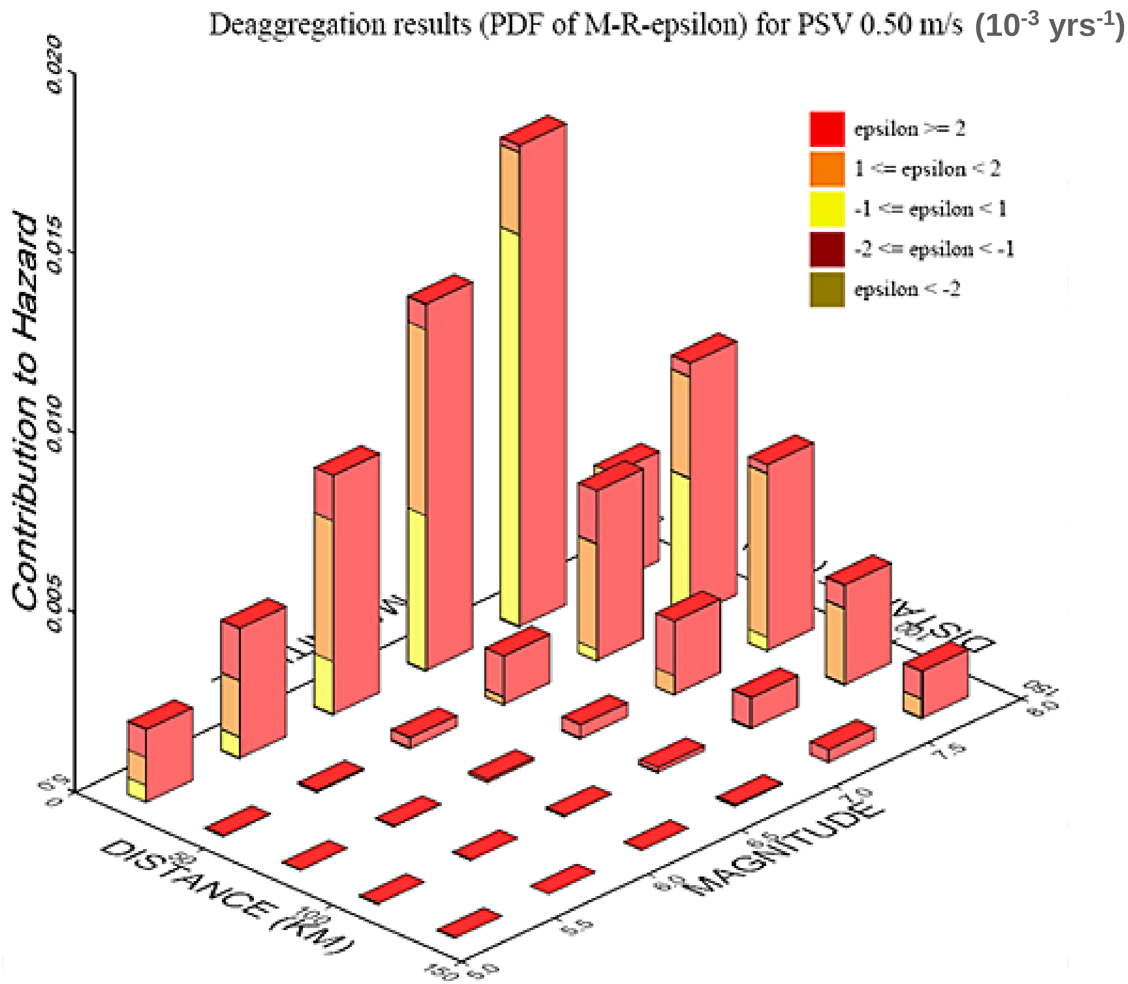
Other Geologic Design Criteria than vibratory effects related to seismic actions
(US R.G. 1.208 – IAEA NS-G-3.3)

- **Determination of Need to Design for Surface Faulting (permanent ground displacements)**
- **Determination of Design Bases for Seismically Induced Floods and Water Waves**
- **Determination of Need to Design for Soil Stability conditions, such as liquefaction, landslides, settlements and loss of bearing capacity**

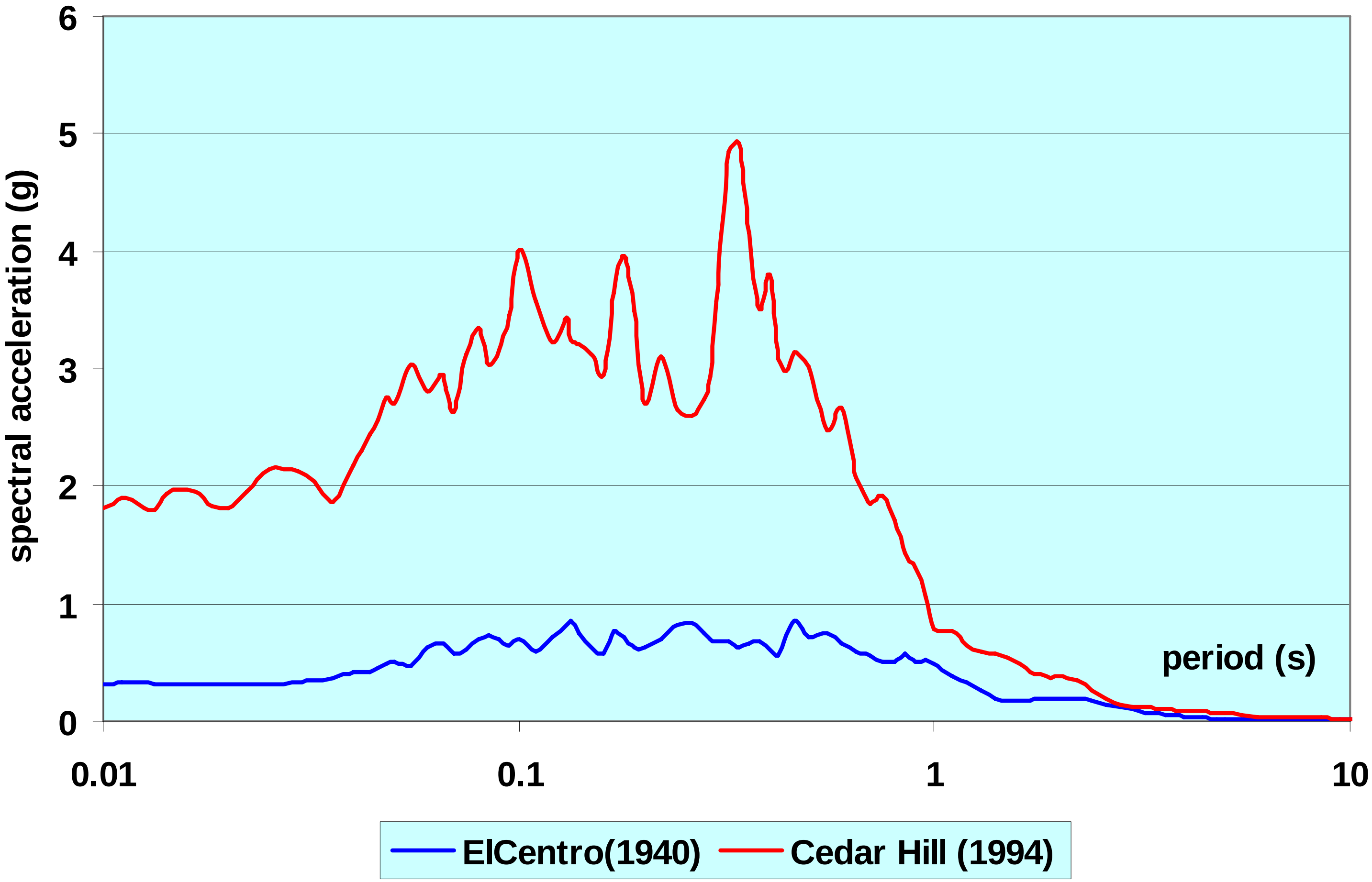
Conclusions

- Ground motion hazards are nowadays based on a combined probabilistic and deterministic approach to fully account for inherent uncertainties, to support each other and to provide a more reliable design
- Improved earthquake monitoring capability and knowledge about active faults give evidence that ground motion values may be larger than considered in the past with relevant implications on the design
- Site-specific vibratory ground motion and induced-effects may strongly affect the stability and design criteria of critical facilities such as NPPs

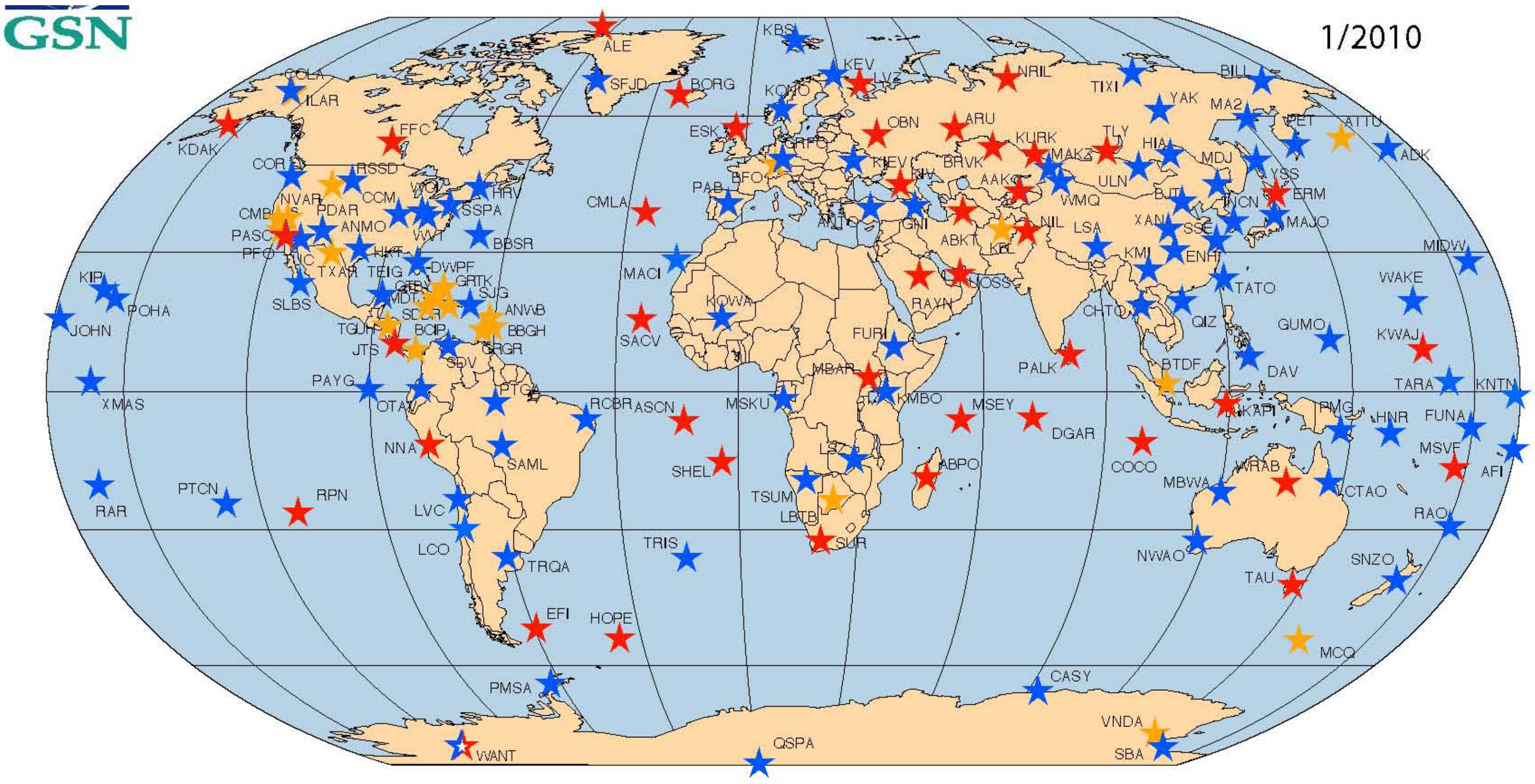
Hazard deaggregation



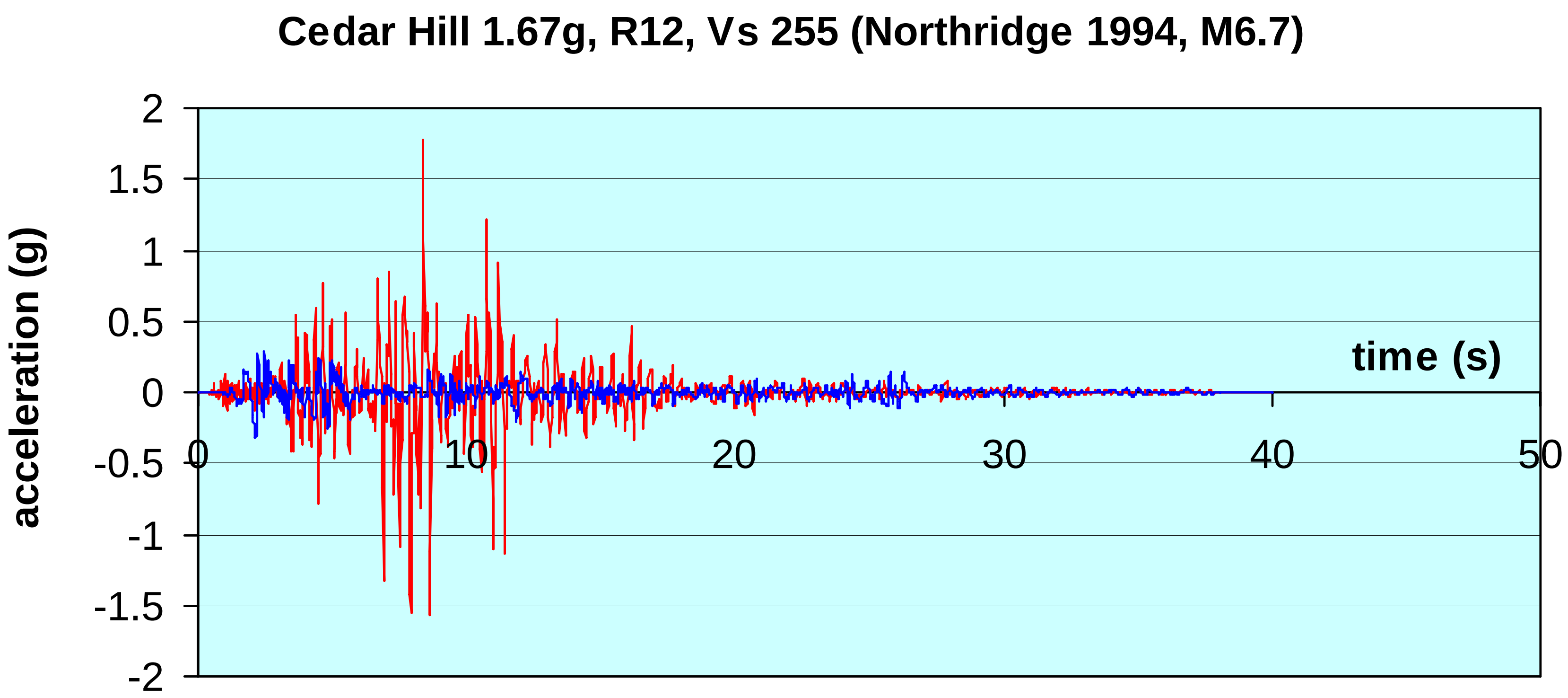
Response spectra



Global Seismographic Network: now over 200 broadband stations



The perception of ground motion hazard: … and after



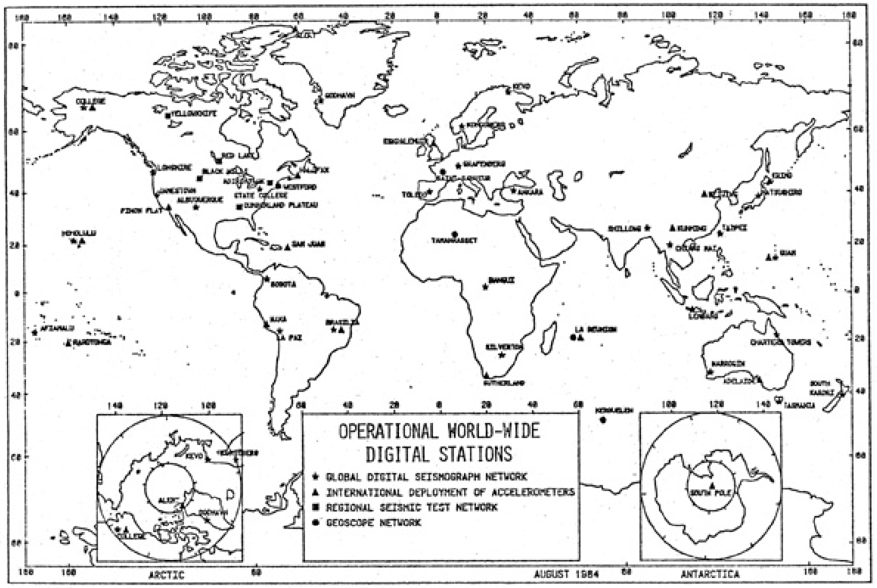


Figure 2.2. Distribution of the operational world wide digital stations.

1984

~45 digital stations

GDSN, RTSN, IDA and GEOSCOPE

2002

~125 GSN stations

~200 station total with FDSN partners

A Global Digital Seismic Array

featuring real-time satellite telemetry from one hundred modern seismographic observatories