Earthquakes, memory loss, & predictability

Laura Peruzza
Seismological Research Center - CRS
National Institute of Oceanography and Applied Geophysics - OGS

① EARTHQUAKES among the relevant natural loss events

② The RISK-PREDICT-REMIND plot

Earthquakes

Earthquakes

Anchorage, Alaska, 1964 M9.2

Kailoura, New Zealand, 2016 M7.8

Central Italy, 2016 M6-6.5

Natural loss events database

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NOT IF, BUT HOW

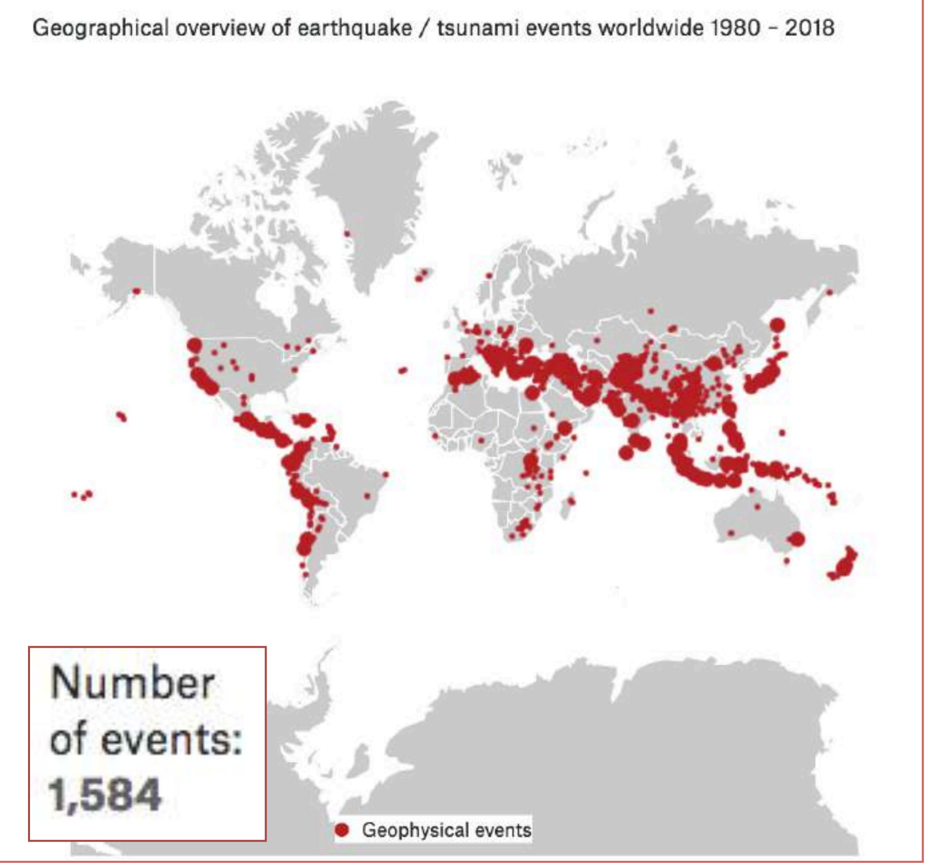
NatCatSERVICE

Natural catastrophe know-how for risk management and research

Many decades of acquired experience in researching, documenting, analysing and evaluation of natural catastrophes have made the NatCatSERVICE one of the most valued data sources for information on natural loss events worldwide. This unique archive provides comprehensive, reliable and professional data on insured, economic and human losses caused by any kind of natural peril.

NOT IF, BUT HOW

Start Analysis



1980-2018

- Geophysical events — Earthquake, tsunami
- Meteorological events — Tropical cyclone
- Hydrological events — Convective storm, Flood
- Climatological events — Wildfire, Heatwave

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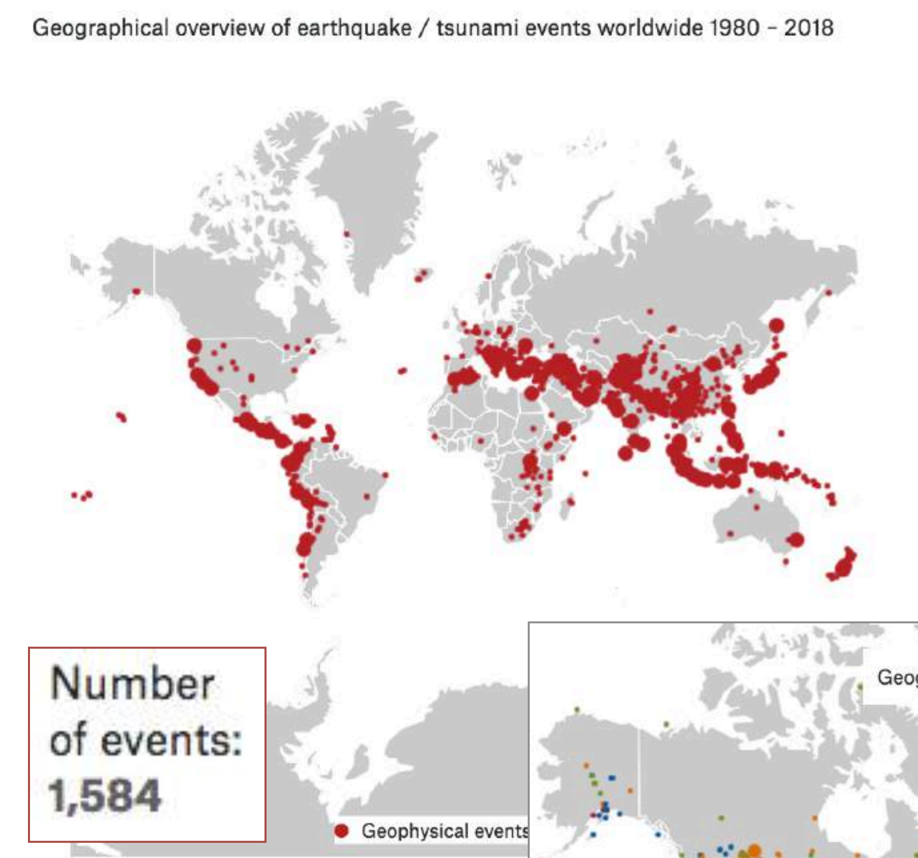
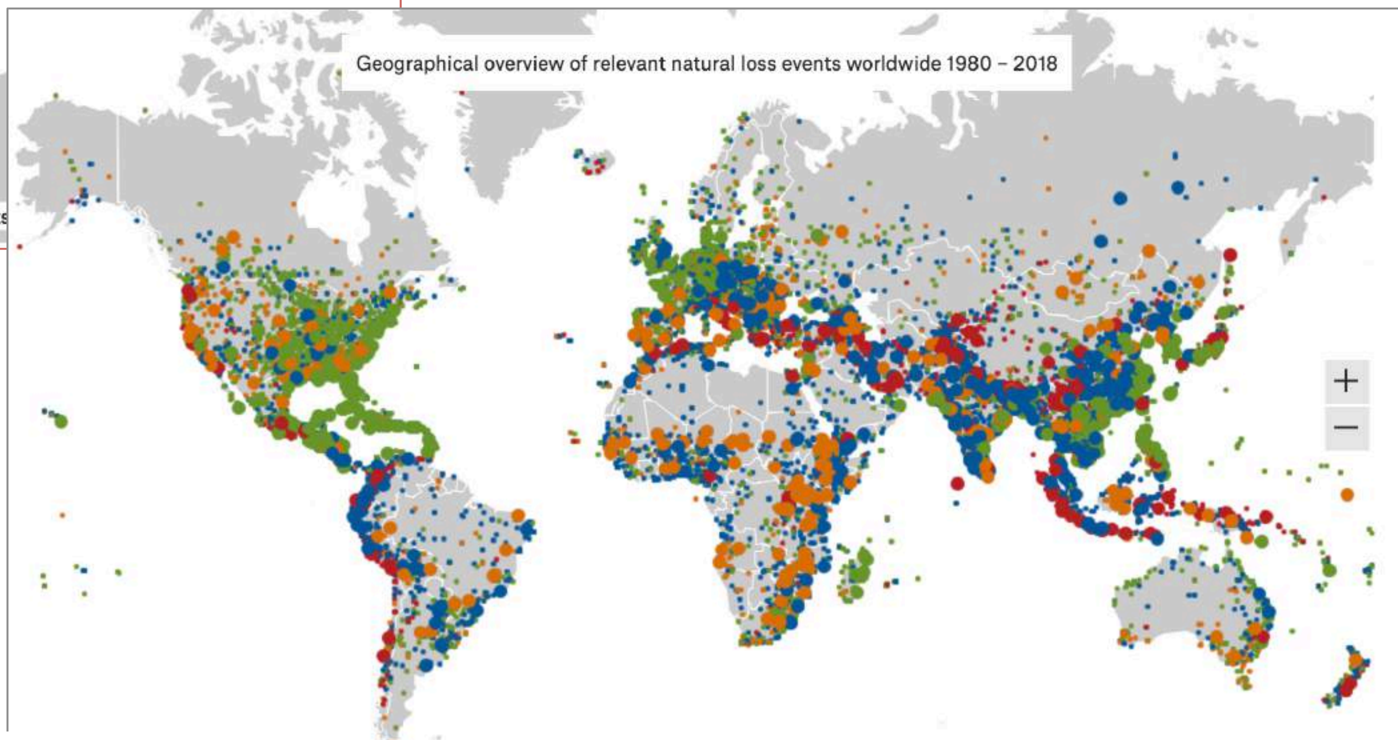
1980-2018





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● Geophysical events ● Meteorological events ● Hydrological events ● Climatological

- Geophysical events — Earthquake, tsunami
- Meteorological events — Tropical cyclone
- Hydrological events — Convective storm, Flood
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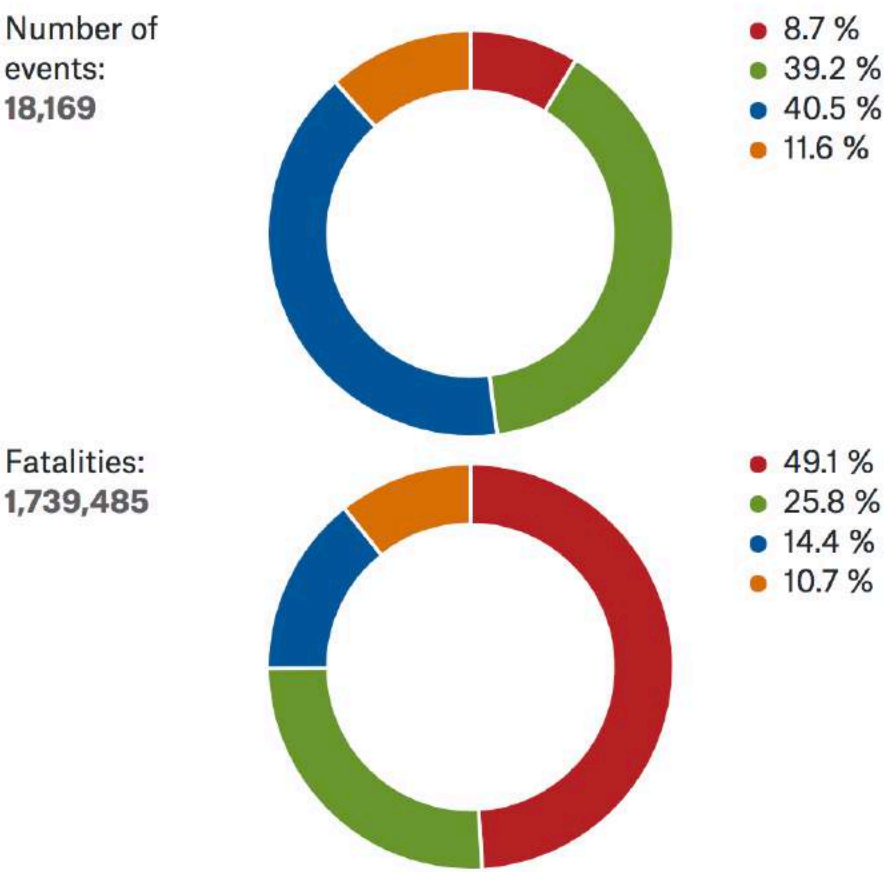
Percentage distribution for relevant natural loss events worldwide 1980 – 2018



Earthquakes & Tsunamis are the least frequent events (<9%) but they cause the highest number of casualties (~ 50%)

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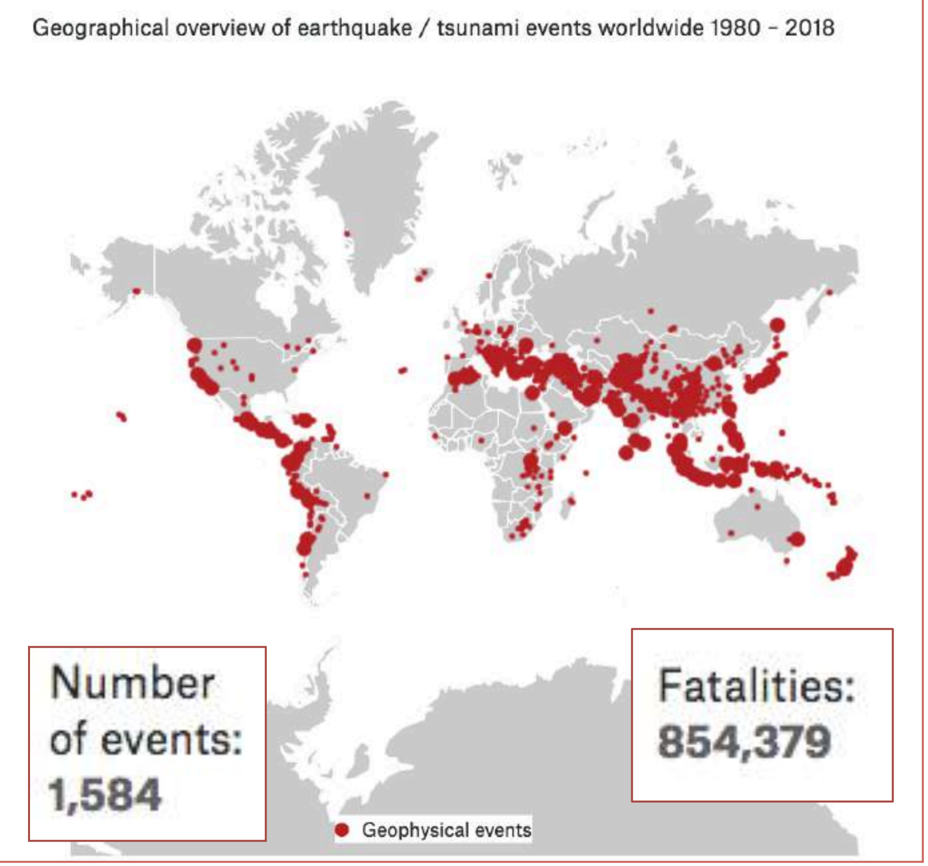
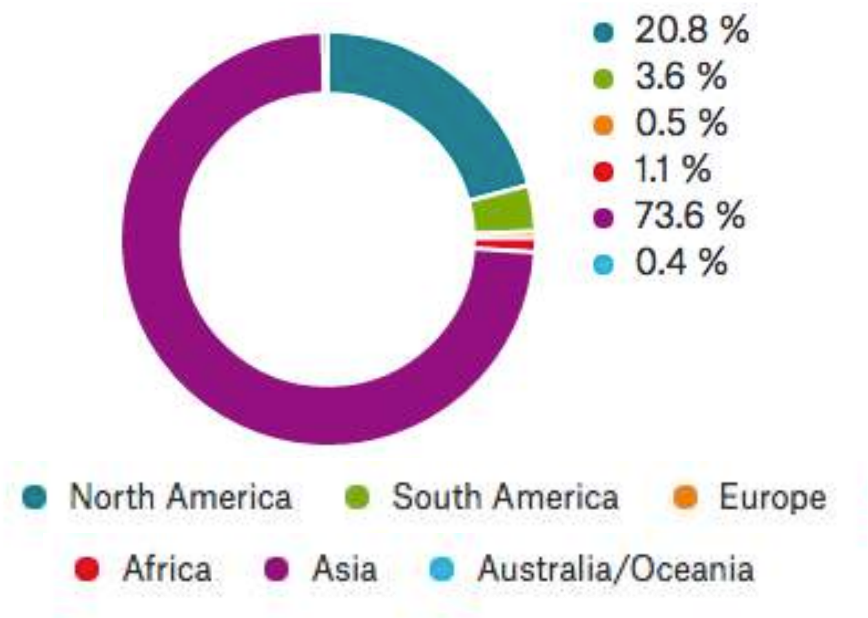


Worldwide fatalities by Earthquakes & Tsunamis

from 1980 to 2018 nearly equal to the actual population of Marseille



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Worldwide fatalities by Earthquakes & Tsunamis

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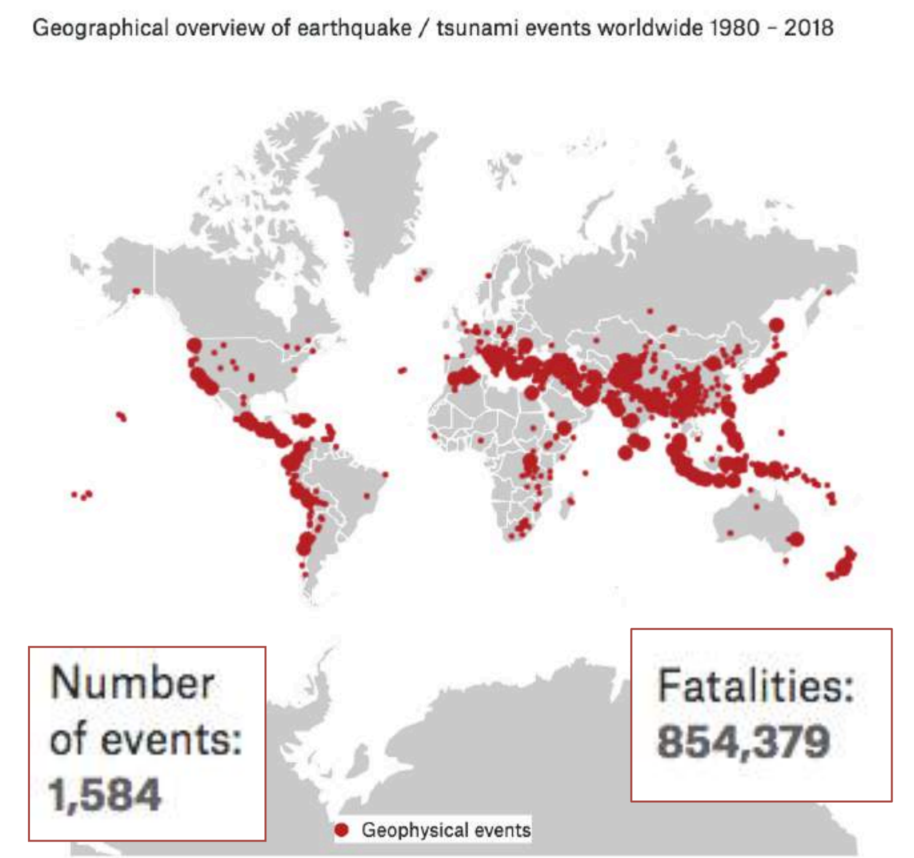

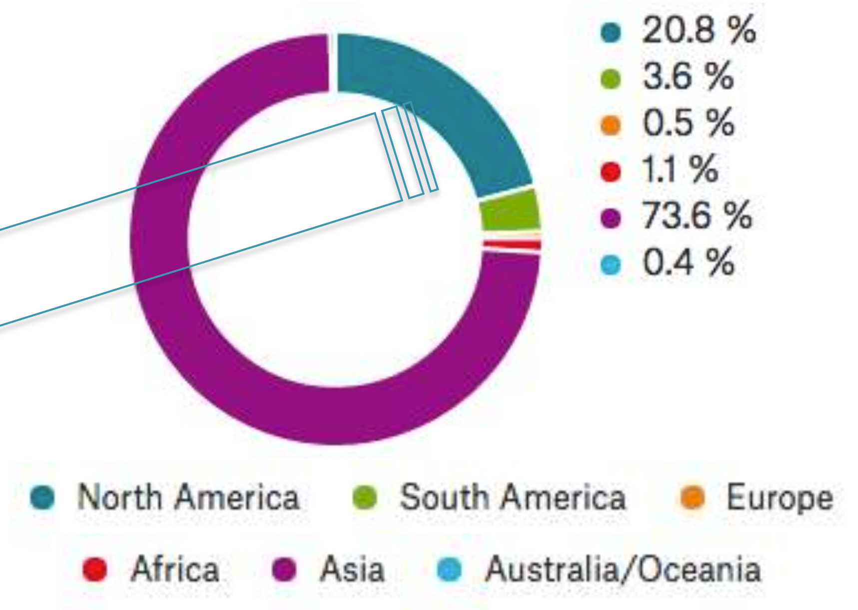

Haiti, 2010
Mexico, 1985

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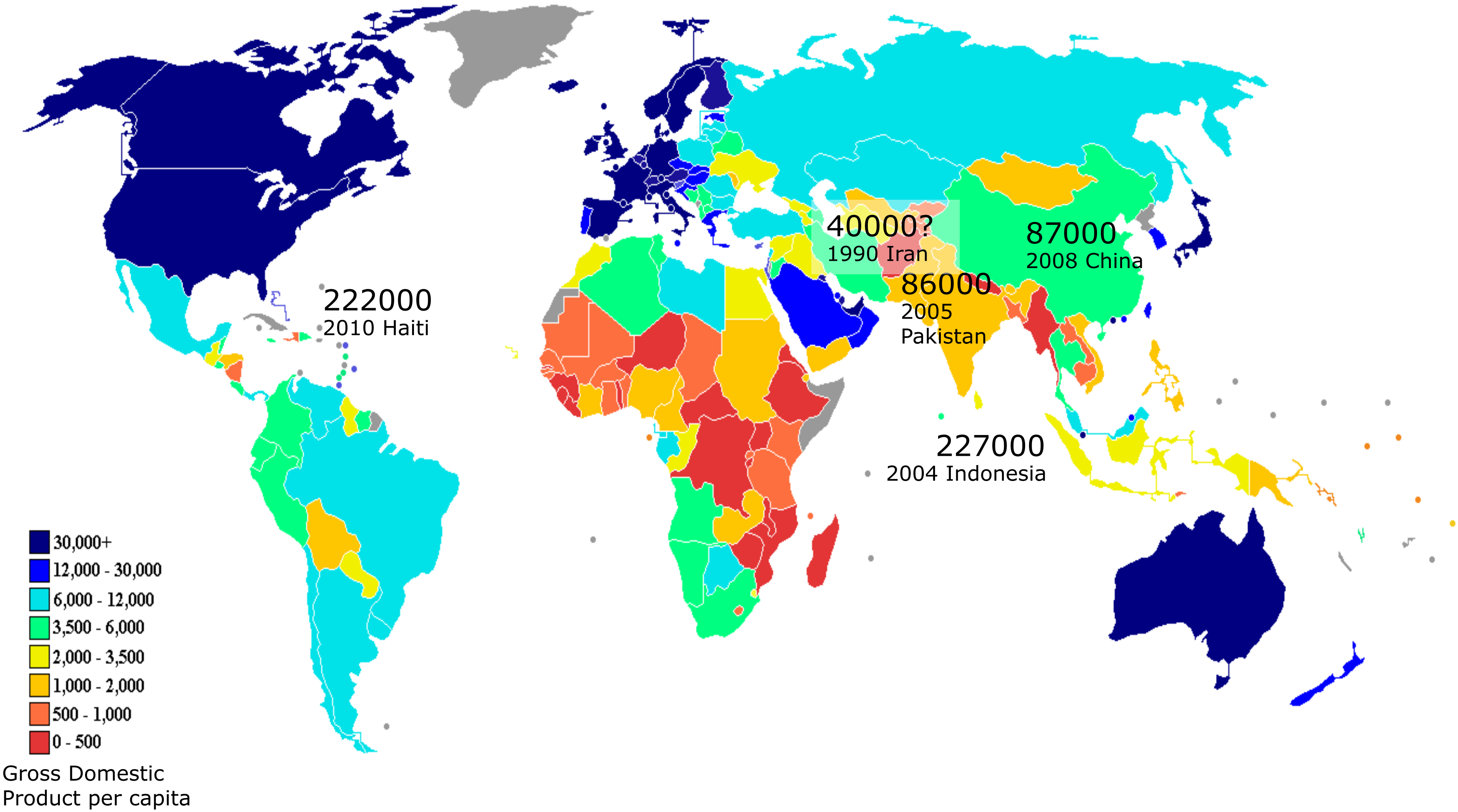
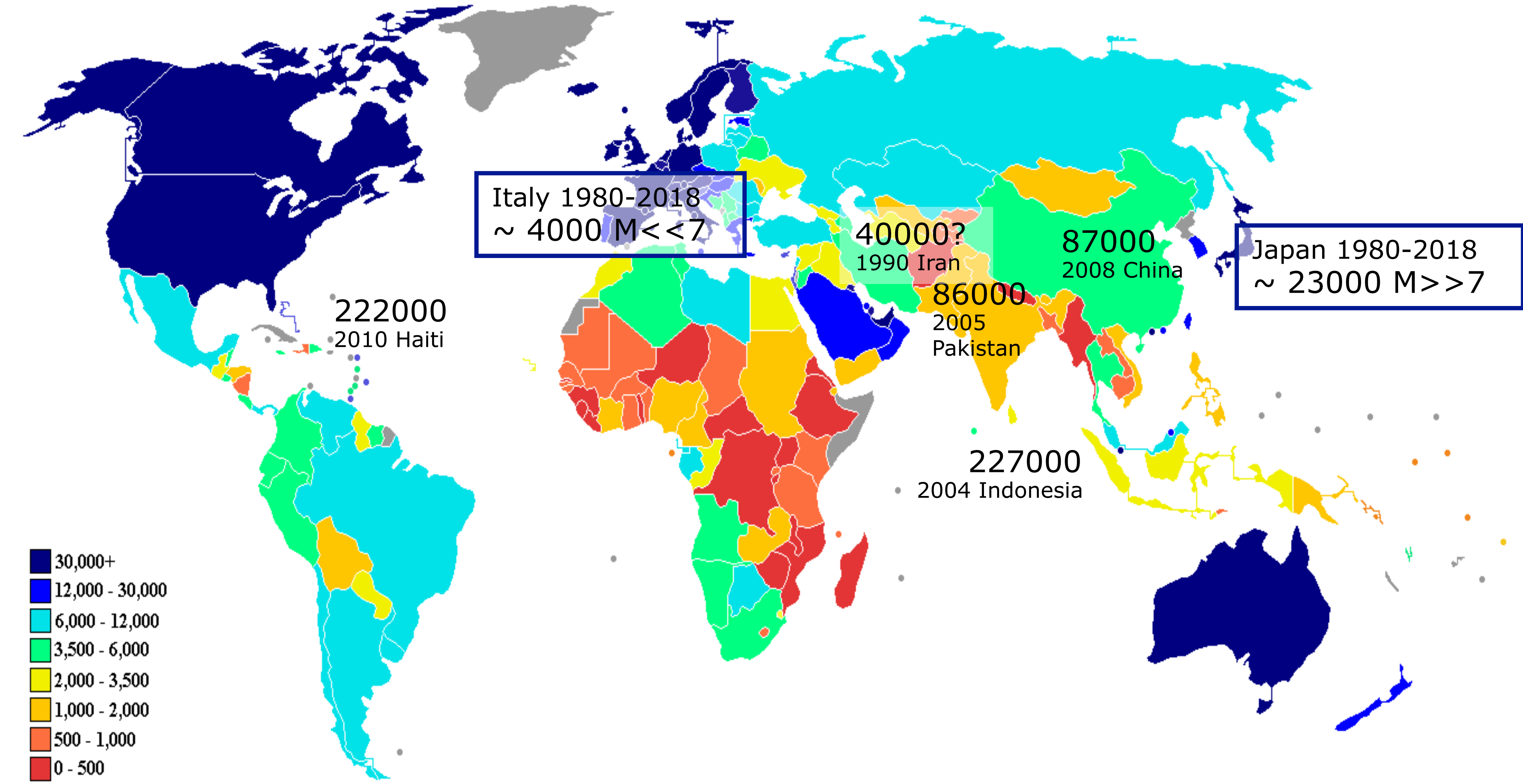
The poorest, the deadliest

26 Dec 2004	Earthquake, tsunami	Indonesia, India, Thailand, Sri Lanka, Maldives, Myanmar, Malaysia, Bangladesh
12 Jan 2010	Earthquake	Haiti: Port-au-Prince, Petionville, Jacmel, Carrefour, Leogane, Petit Goave, Gressier
8 Oct 2005	Earthquake	Pakistan, India, Afghanistan
12 May 2008	Earthquake	China: Sichuan, Mianyang, Beichuan, Wenchuan, Shifang, Chengdu, Guangyuan, Ngawa, Ya'an, Ziyang, Meishan, Suining, Garzê, Neijiang, Gansu, Shaanxi, Chongqing, Yunnan, Maoxian
20 Jun 1990	Earthquake	Iran, Islamic Republic of: Caspian Sea, Gilan province, Manjil, Rudbar, Zanjan, Safid, Qazvin

The poorest, the deadliest

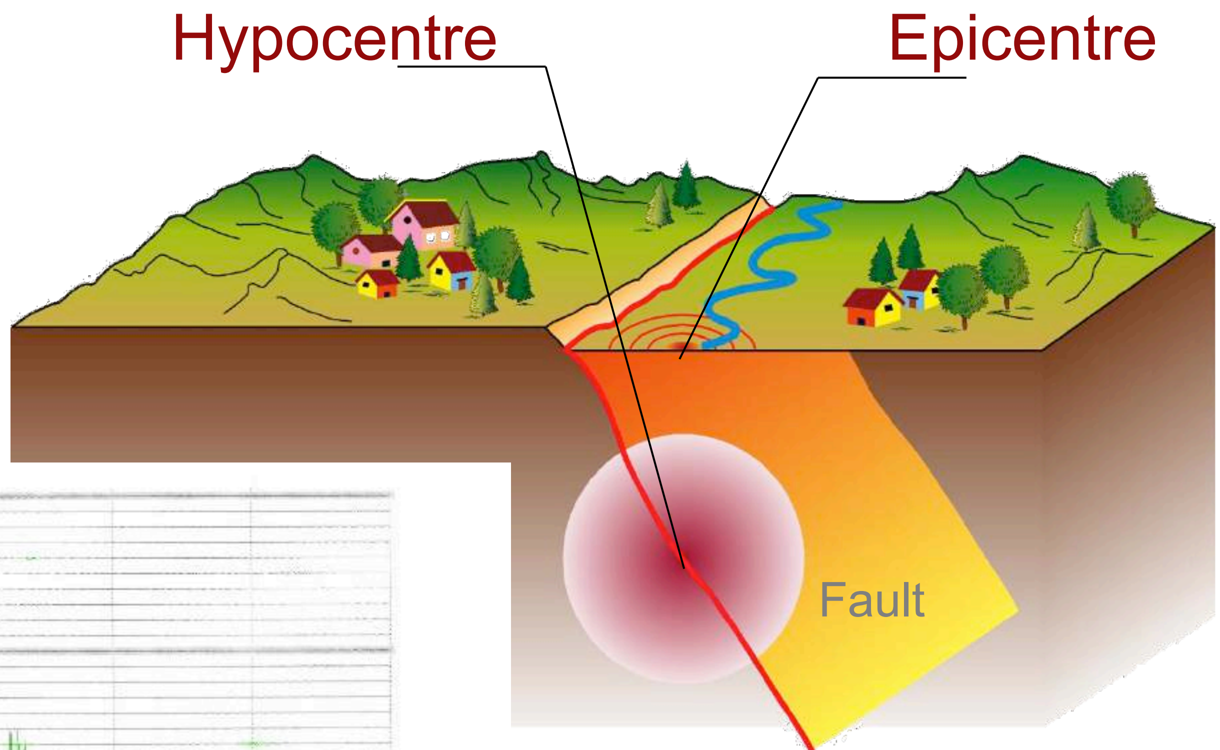


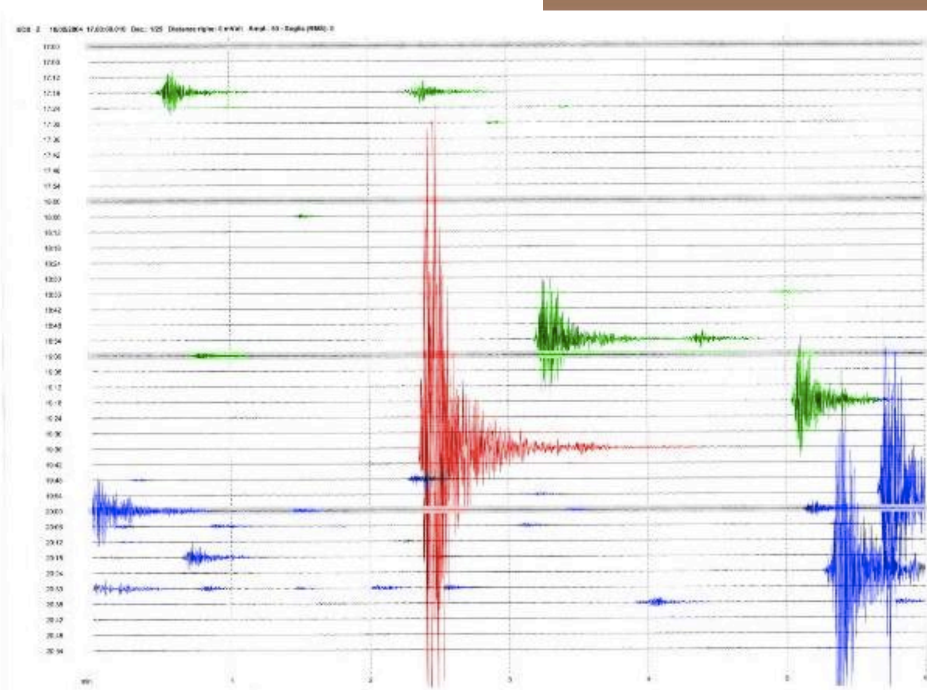
… with some exceptions



Gross Domestic
Product per capita

Magnitude, measure of energy



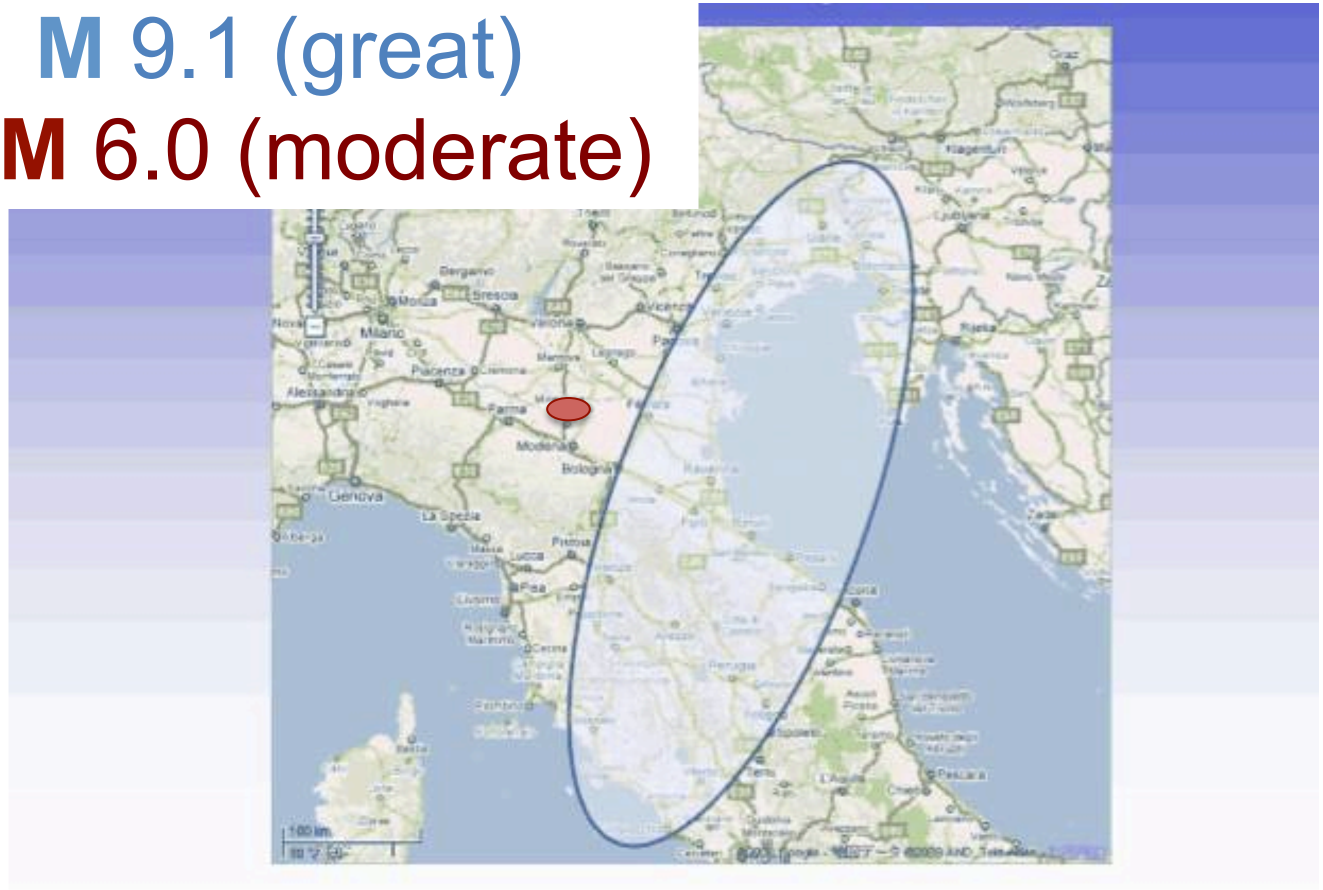


Magnitude is a conventional measure obtained from a seismographic record

Magnitude = f(Rupture size)

Tohoku 2011 **M** 9.1 (great)

Emilia 2012 **M** 6.0 (moderate)

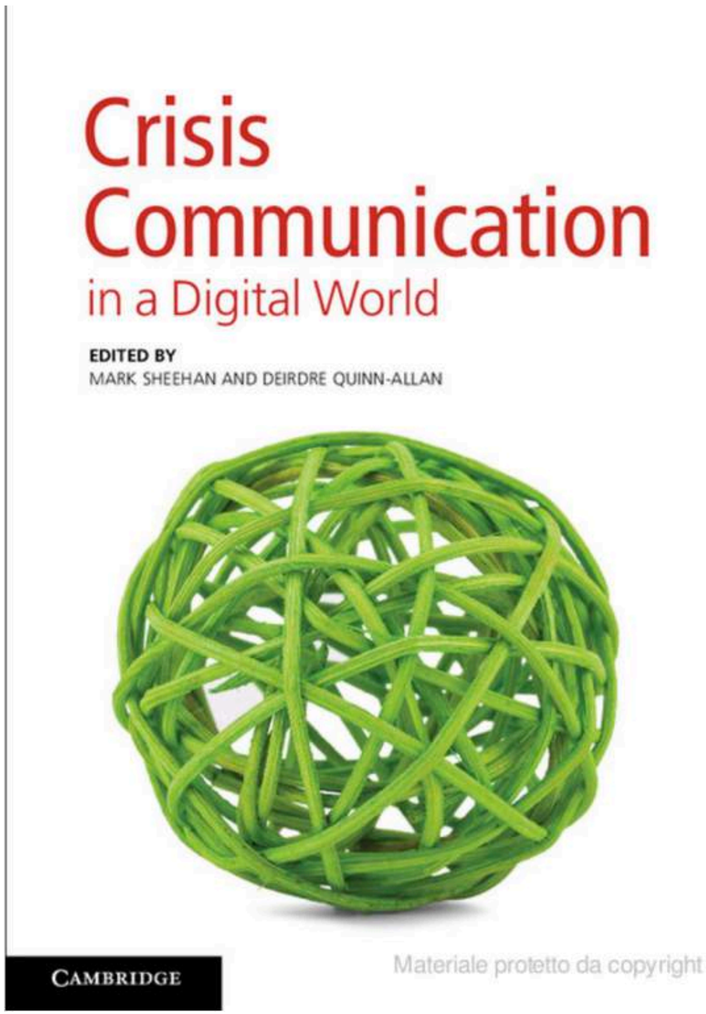


Consequences of earthquakes can be global

Tohoku 2011 **M** 9.1
(~16000 deaths,
~2500 missing)

Emilia 2012 **M** 6.0
(27 deaths)

World Dialysis Crisis, Emilia 2012



again. Foremost among the gossip was the story that Gambro would cease production in the region completely. So, on this third crisis front, misinformation and rumour threatened to damage Gambro's relationship with the very community that would play an important role in **disaster** recovery. The media, having exhausted the human interest angle of the earthquake (for example, the sad loss of life and historic buildings), began to pursue the corporate angle. It picked up the story from the 2011 restructure that Gambro might leave the region – a story that was likely to panic the already-fragile population after the earthquake.

Disaster: A physical event leading to crisis – normally not initiated by human interaction – such as earthquake, tsunami and bushfires.

However, strong communication channels and the long-term stakeholder relationships were used to contradict the rumour and assuage fears of such a development at a pivotal time in the region's history. In addition the quick recovery at the plant and stakeholder belief in the company's assurances were based on the relational framework and trust Gambro had developed since establishing itself in the region in the 1960s.

The earthquakes: From one disaster to another

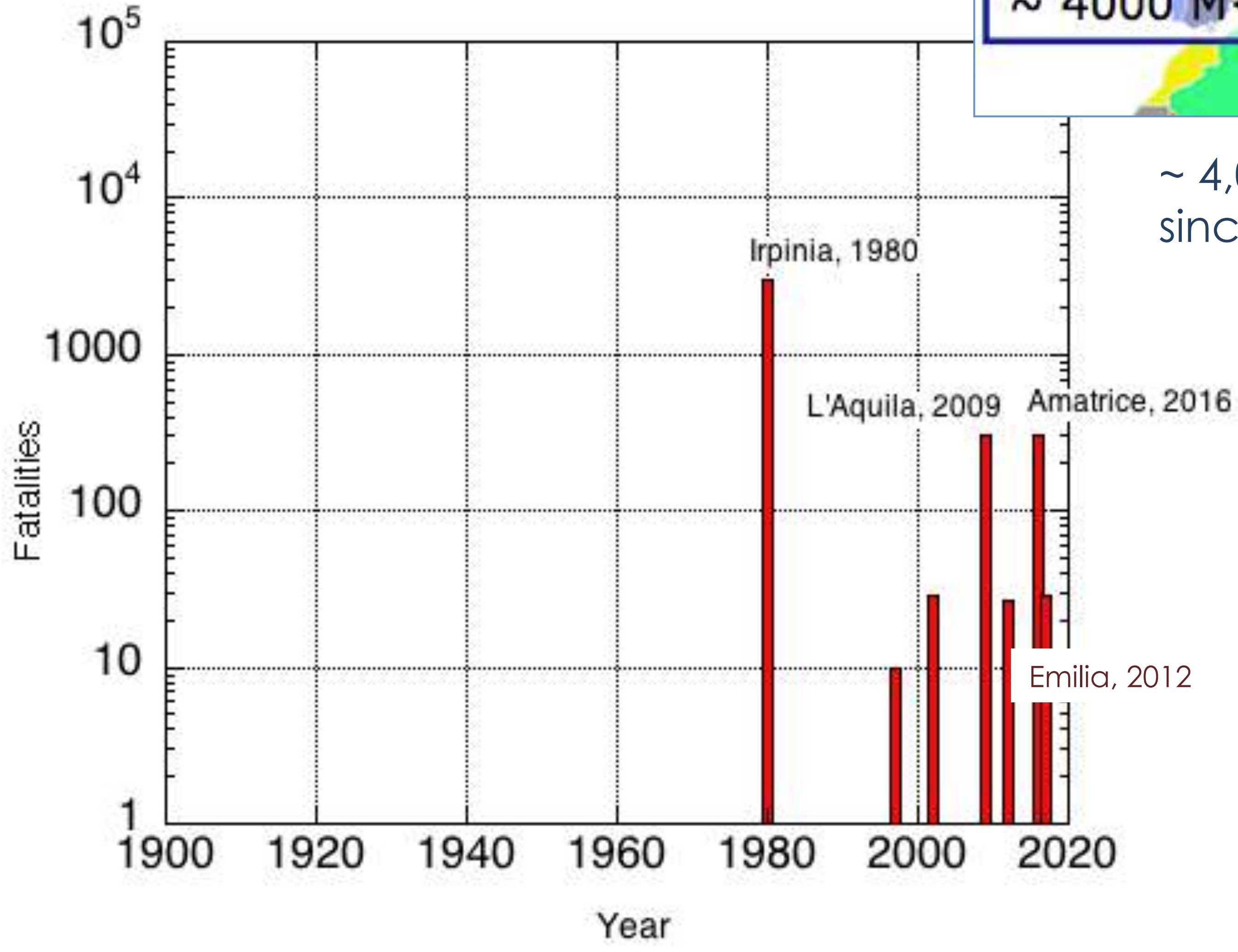
On 21 May 2012, a major earthquake of 5.9 magnitude hit the Medolla region. Gambro's monitor and bloodline production buildings and distribution centre were damaged in the earthquake and the injection moulding (**bloodline**) production areas of the facility could not be accessed. It was fortunate that as it was a Sunday there were limited staff on the premises. The plant was able to recover partially. Less than five days after the earthquake limited production of dialysis monitors commenced and Gambro was able to begin distribution from its warehouse in Medolla.

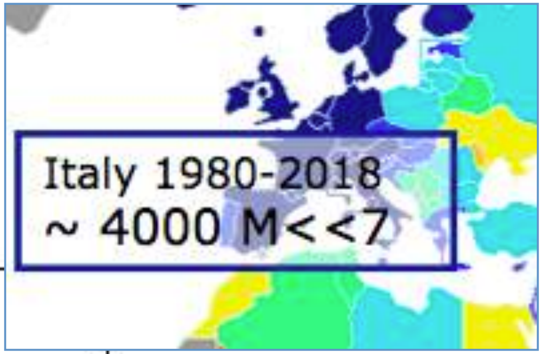
Bloodlines: Specially manufactured, highly specified tubes that run a patient's blood to the dialysis machine (monitor) and back to the patient.

Just as Gambro Medolla and its Crisis Task Force Team (CTFT) were coming to terms with the devastation and handling the situation as laid down in the company's crisis management plan and procedures, a second earthquake hit. This quake happened on 29 May 2012, at a magnitude of 5.8, and Medolla was at its epicentre, much closer to the factory; the result was devastating. To make matters worse, in the weeks that followed the second quake, the region was subject to several hundred aftershocks, which affected those buildings that had not already been damaged or destroyed. Gambro's plant and distribution were similarly affected. Distribution ceased and the factory went in shutdown mode, operating with a skeleton staff, including the CTFT.

Although before 20 May, Gambro was ready for crisis situations, including restructure, takeover and earthquake, no amount of planning can fully prepare an organisation for a total dislocation caused by such a disaster. Although no Gambro employees were injured, life was difficult. Many local residents in Medolla had been sleeping in cars and tents since the first earthquake, and the second forced many more from their homes. Other factors of a more intangible nature were also evident; an Italian Red Cross spokesperson stated that 'The psychological impact of having two

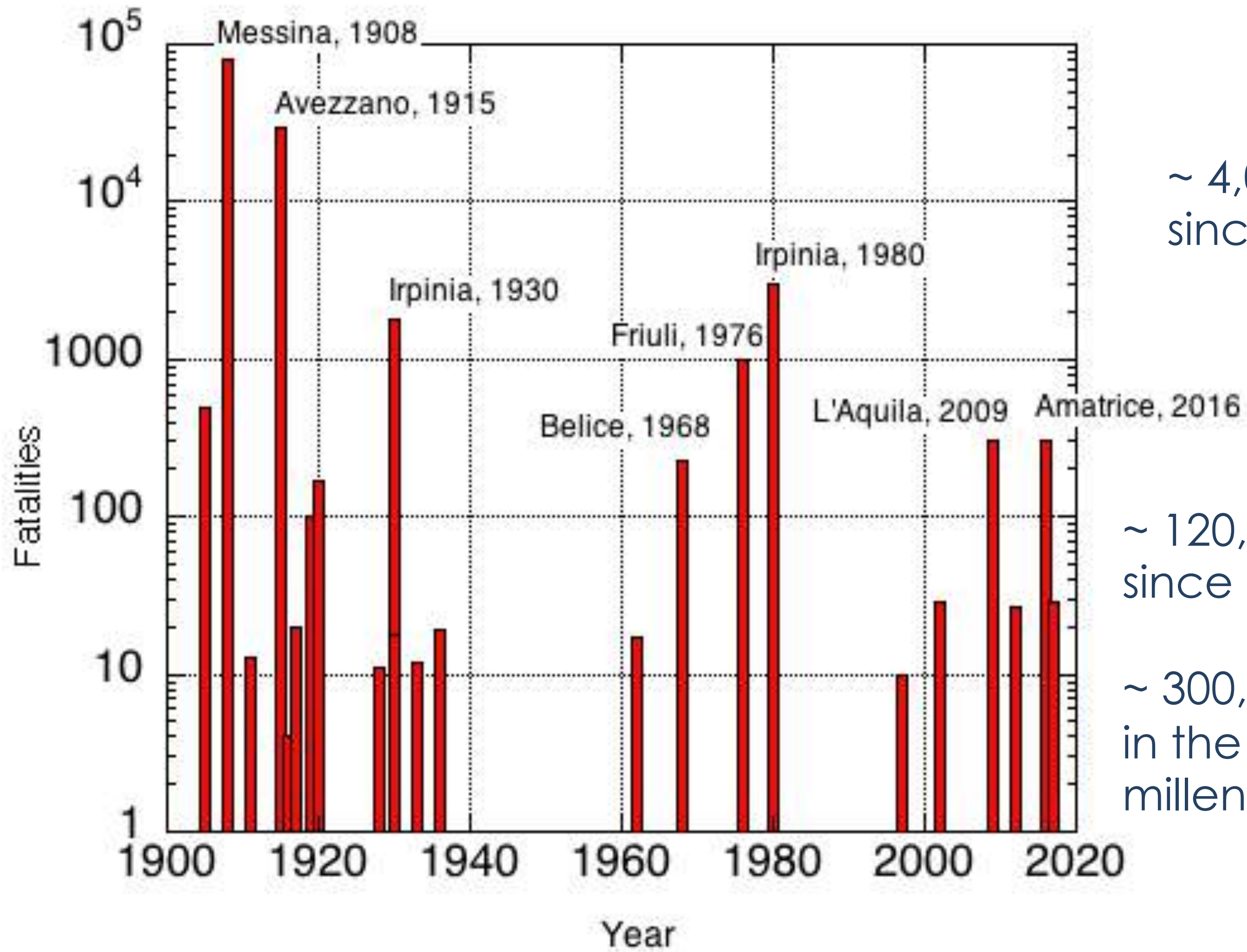
Italy





~ 4,000 deaths since 1980

Italy, a deadly seismic country

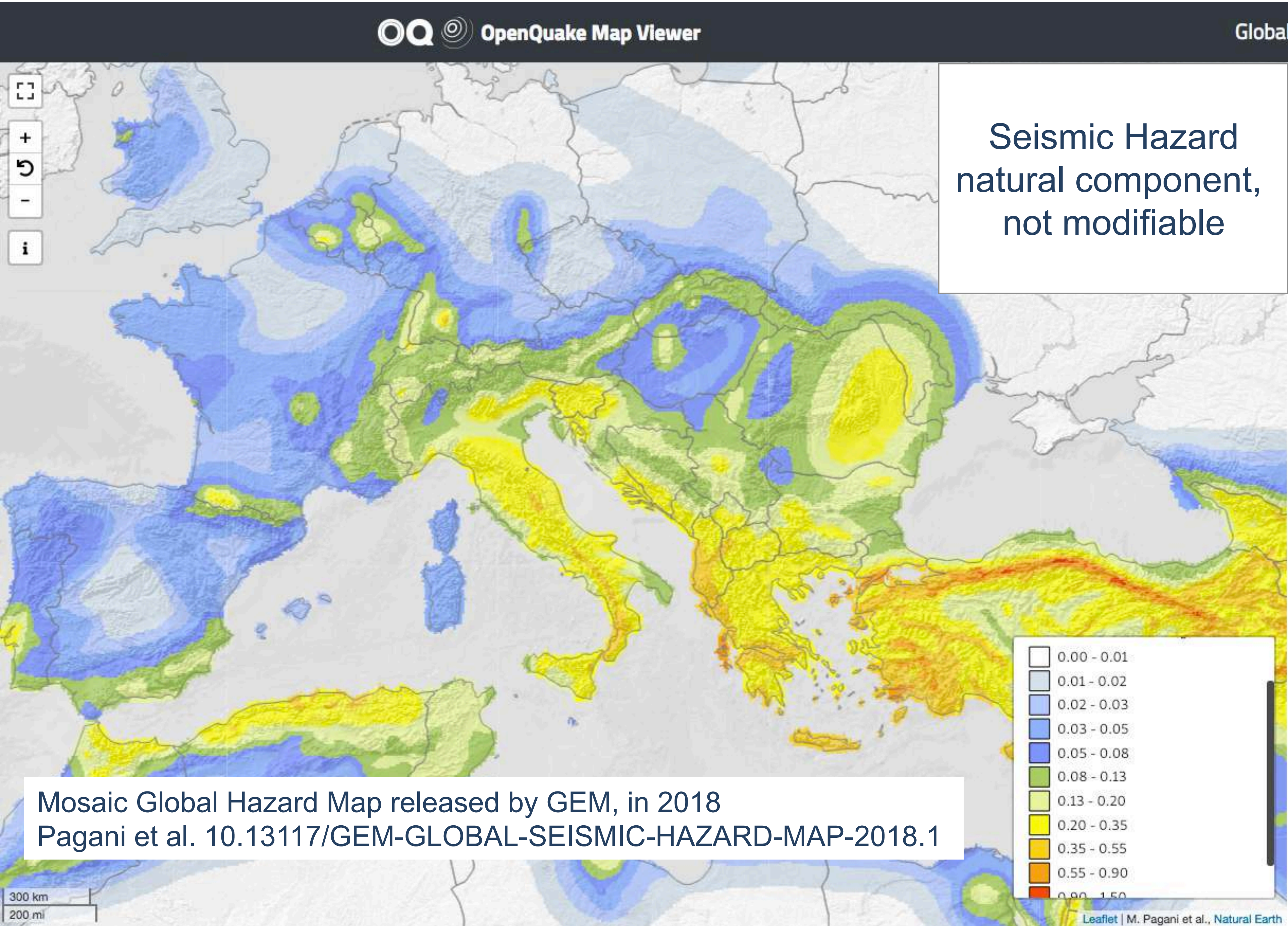


~ 4,000 deaths since 1980

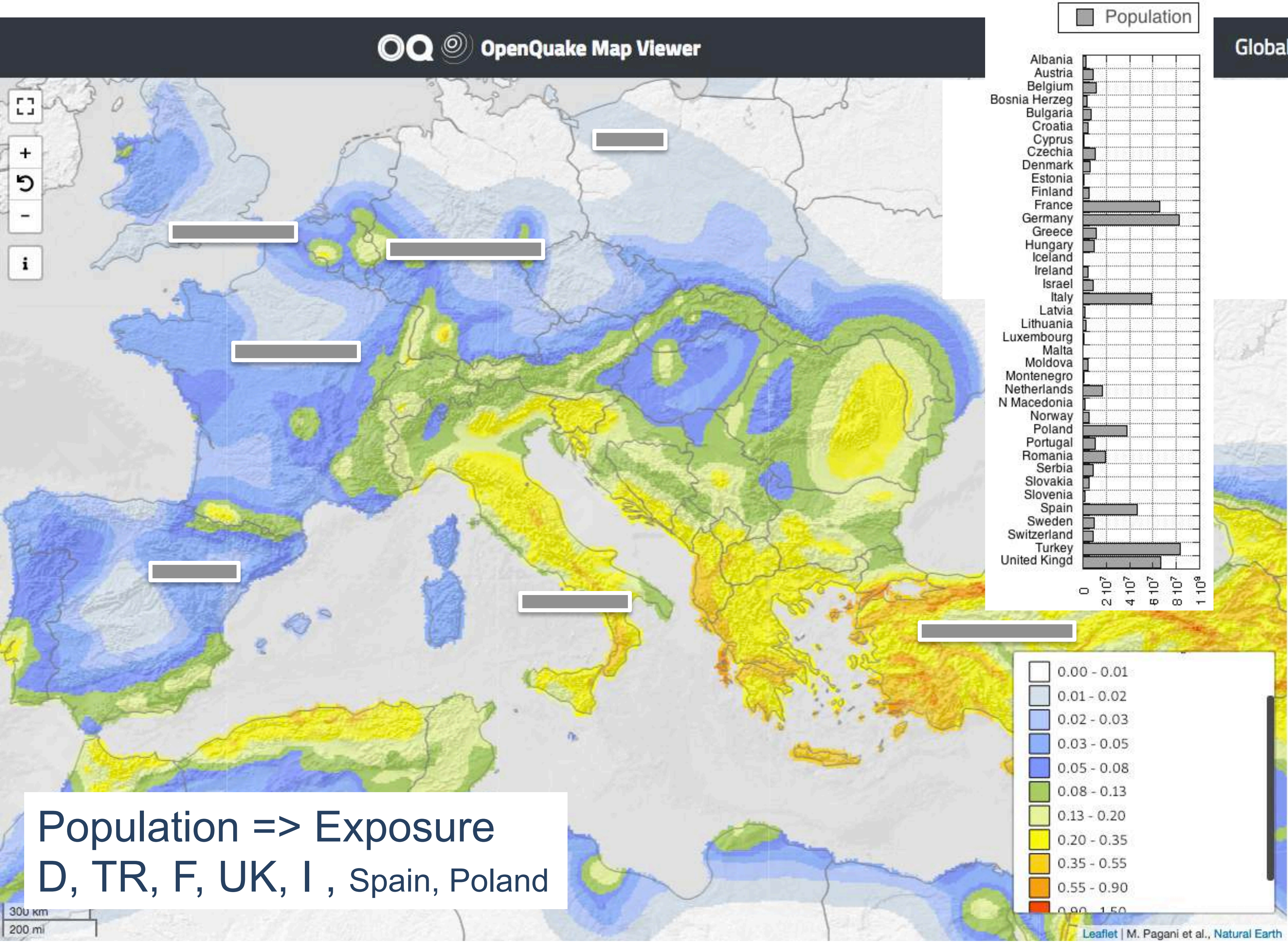
~ 120,000 deaths since 1900

~ 300,000 deaths in the last millennium

Seismic Hazard natural component, not modifiable

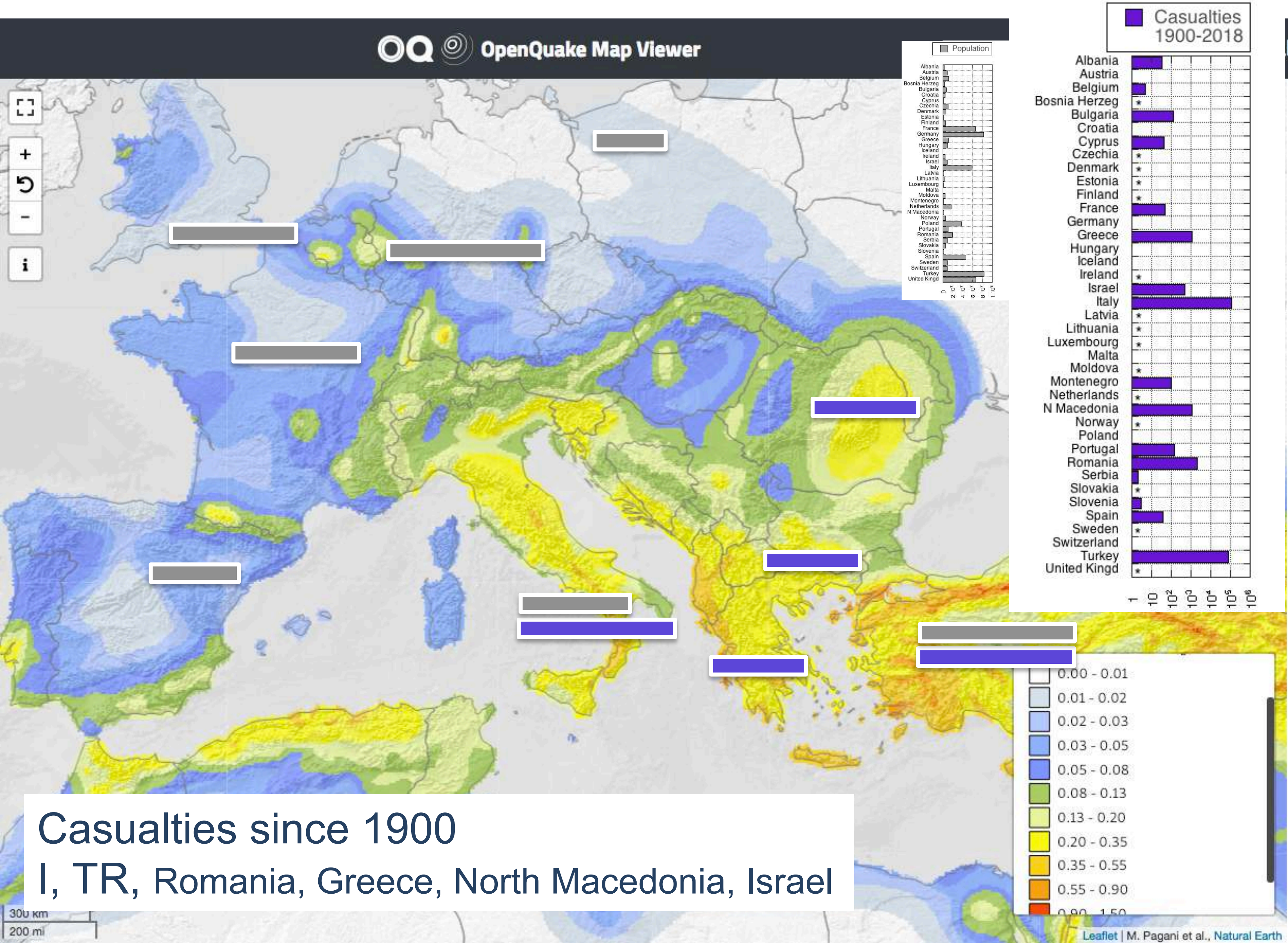


Mosaic Global Hazard Map released by GEM, in 2018
Pagani et al. 10.13117/GEM-GLOBAL-SEISMIC-HAZARD-MAP-2018.1

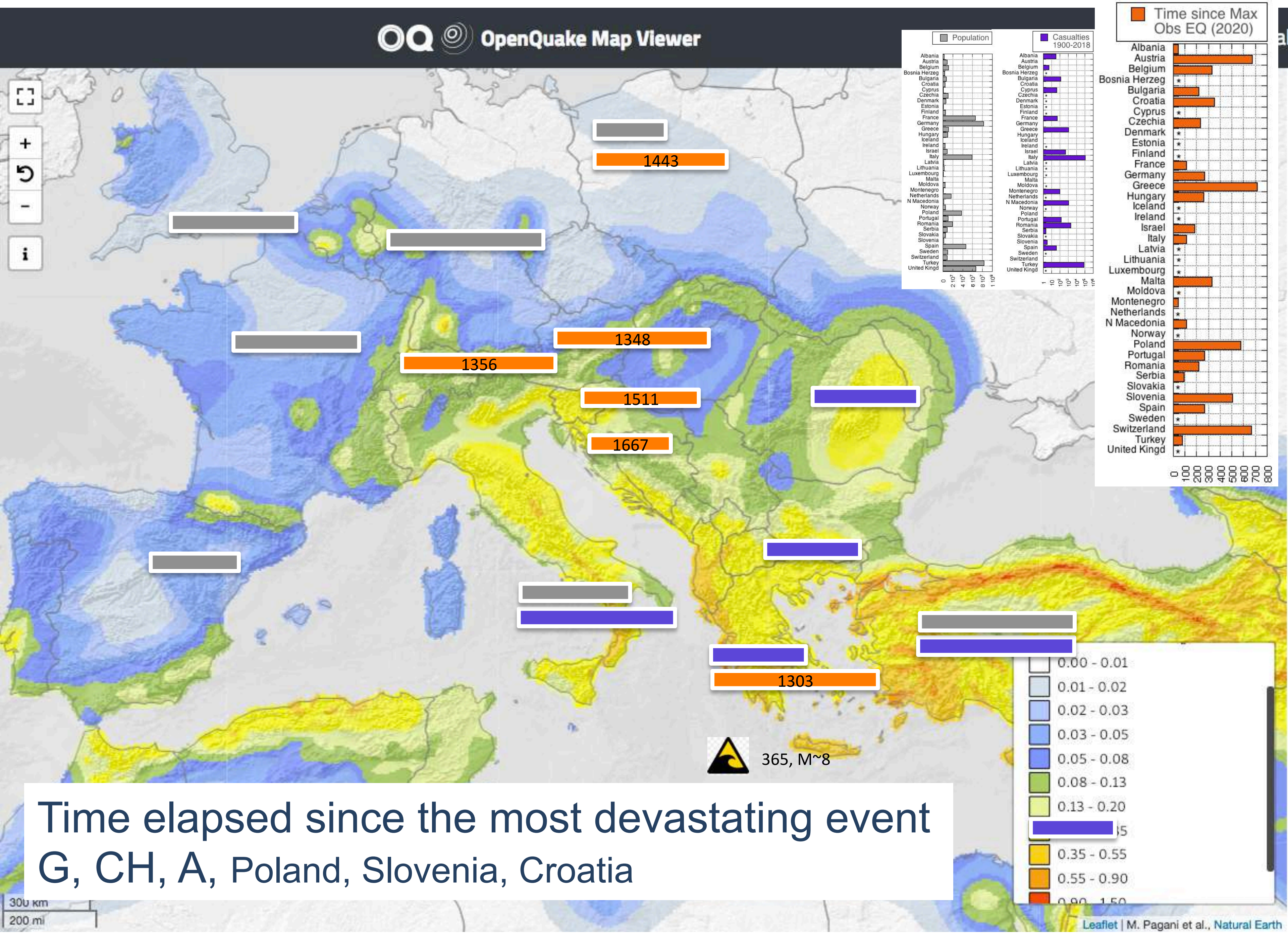


Population => Exposure

D, TR, F, UK, I , Spain, Poland



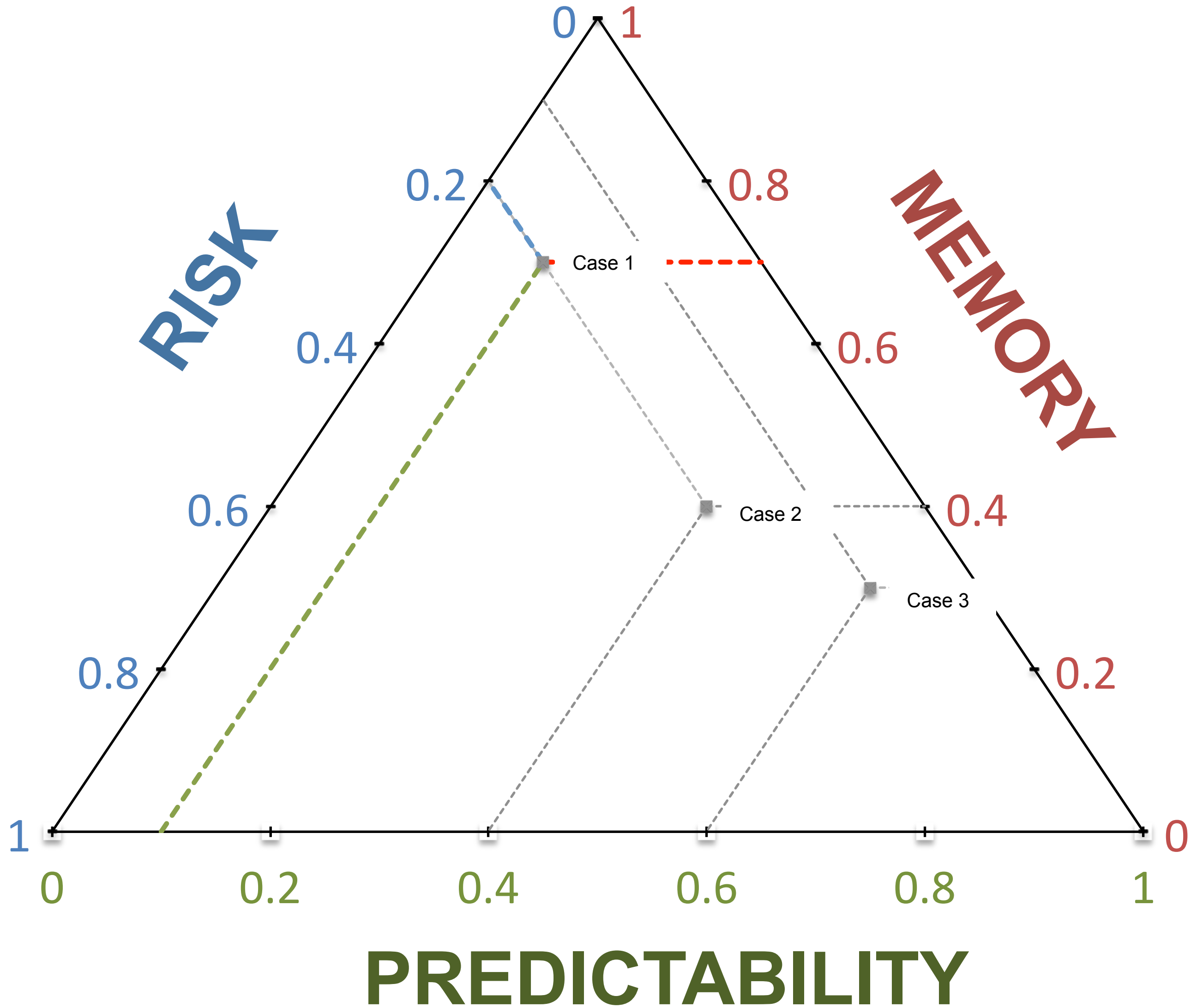
OpenQuake Map Viewer
Population
Casualties 1900-2018
Albania
Austria
Belgium
Bosnia Herzeg
Bulgaria
Croatia
Cyprus
Czechia
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Israel
Italy
Latvia
Lithuania
Luxembourg
Malta
Moldova
Montenegro
Netherlands
N Macedonia
Norway
Poland
Portugal
Romania
Serbia
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
United Kingd
1 10 10^2 10^3 10^4 10^5 10^6
0.00 - 0.01
0.01 - 0.02
0.02 - 0.03
0.03 - 0.05
0.05 - 0.08
0.08 - 0.13
0.13 - 0.20
0.20 - 0.35
0.35 - 0.55
0.55 - 0.90
0.90 - 1.50
Casualties since 1900
I, TR, Romania, Greece, North Macedonia, Israel
300 km
200 mi
Leaflet | M. Pagani et al., Natural Earth



Time elapsed since the most devastating event

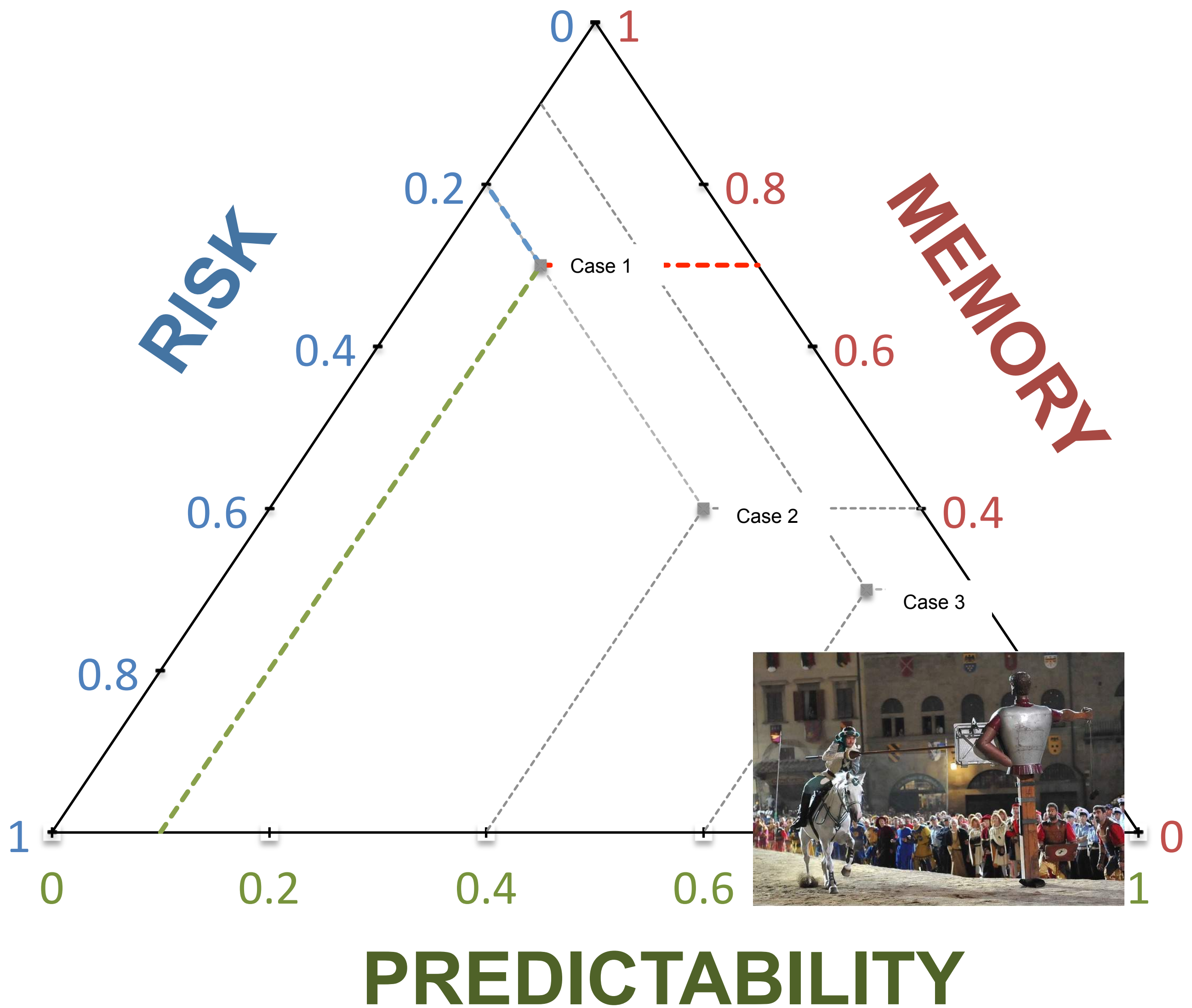
G, CH, A, Poland, Slovenia, Croatia

② The RISK-PREDICT-REMIND ternary plot



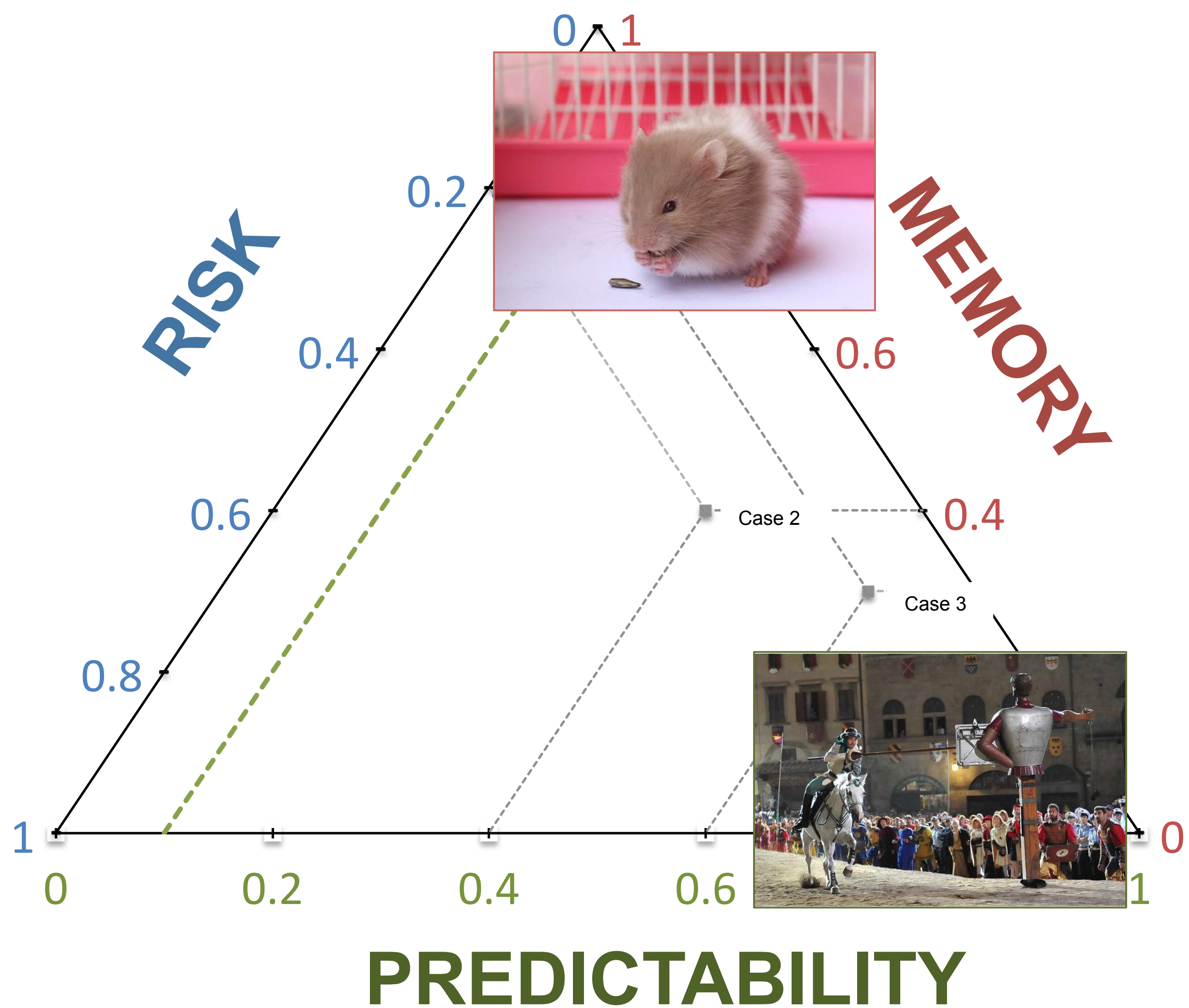
Predictability -> 1

Predictability -> 1, Risk -> 0

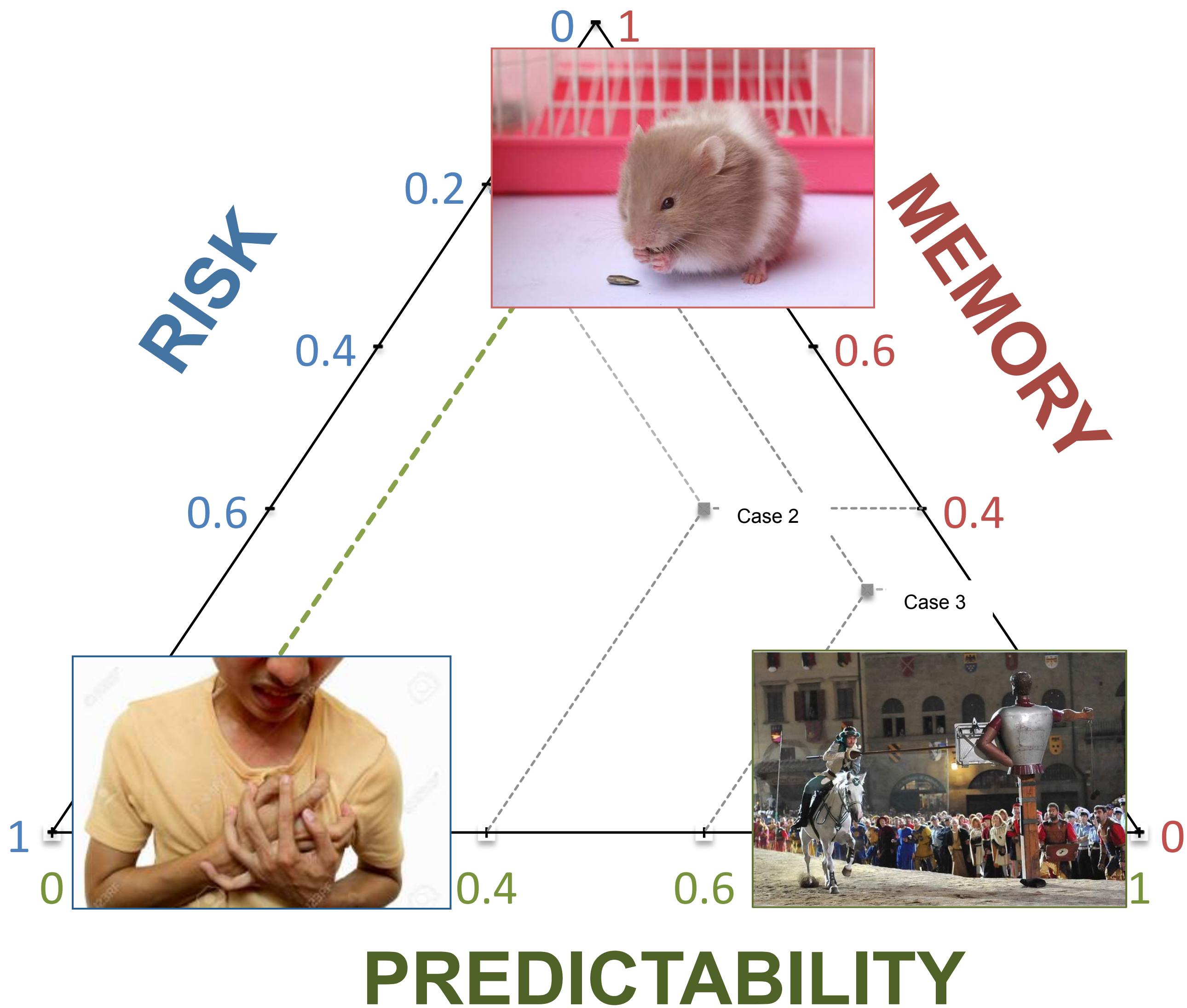


Memory -> 1

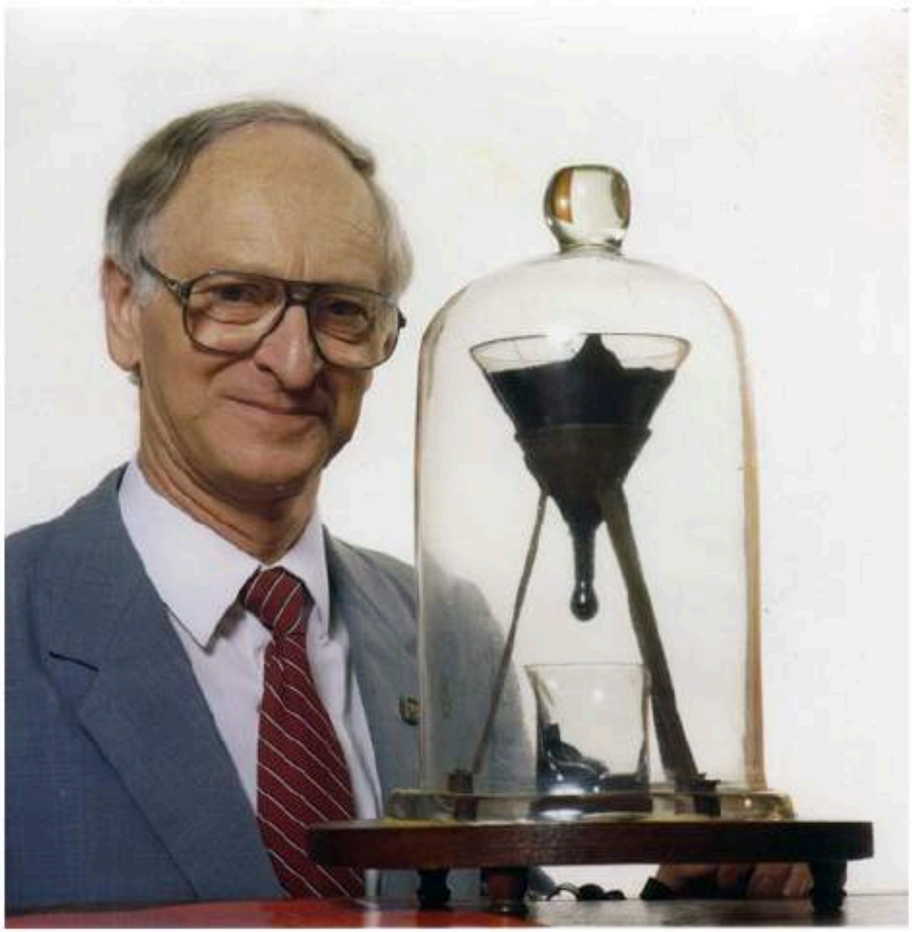
Memory -> 1, Risk -> 0



P -> 0, M -> 0, Risk -> 1


RISK
MEMORY
PREDICTABILITY
0
1
0.2
0.4
0.6
1
0
0.6
0.4
0
0.4
0.6
1
Case 2
Case 3

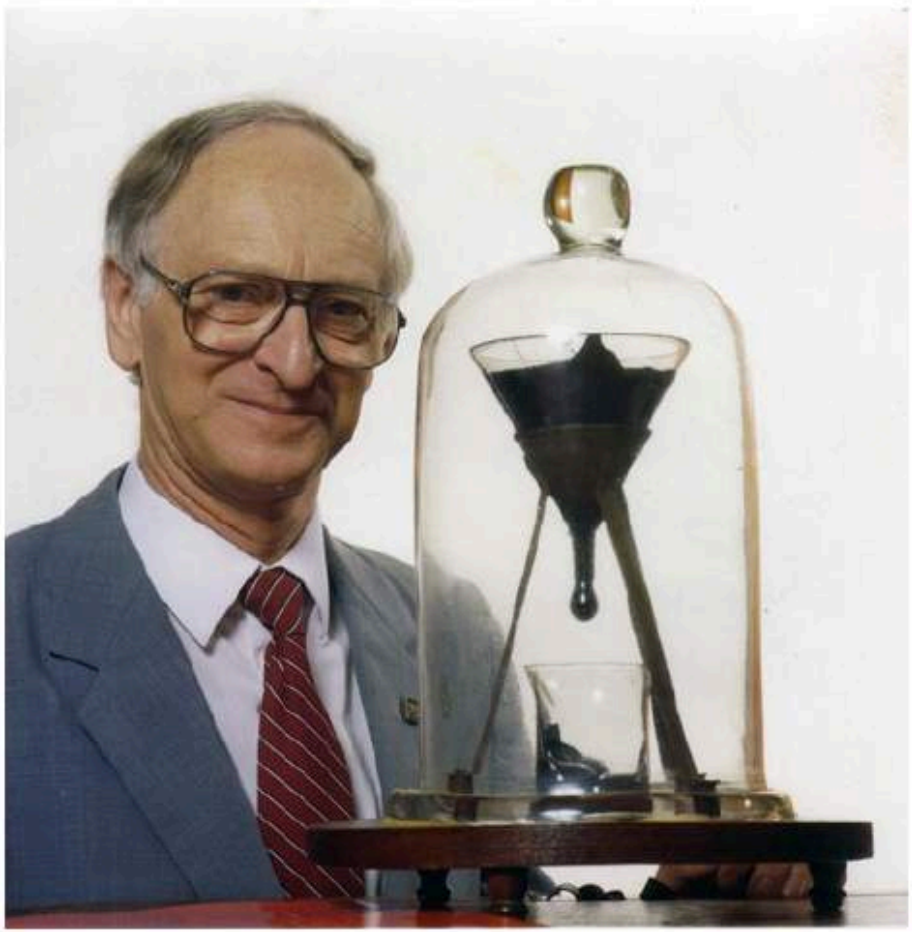
Predictability



A reliable forecast has to answer three questions:

1) WHAT
2) WHERE
3) WHEN

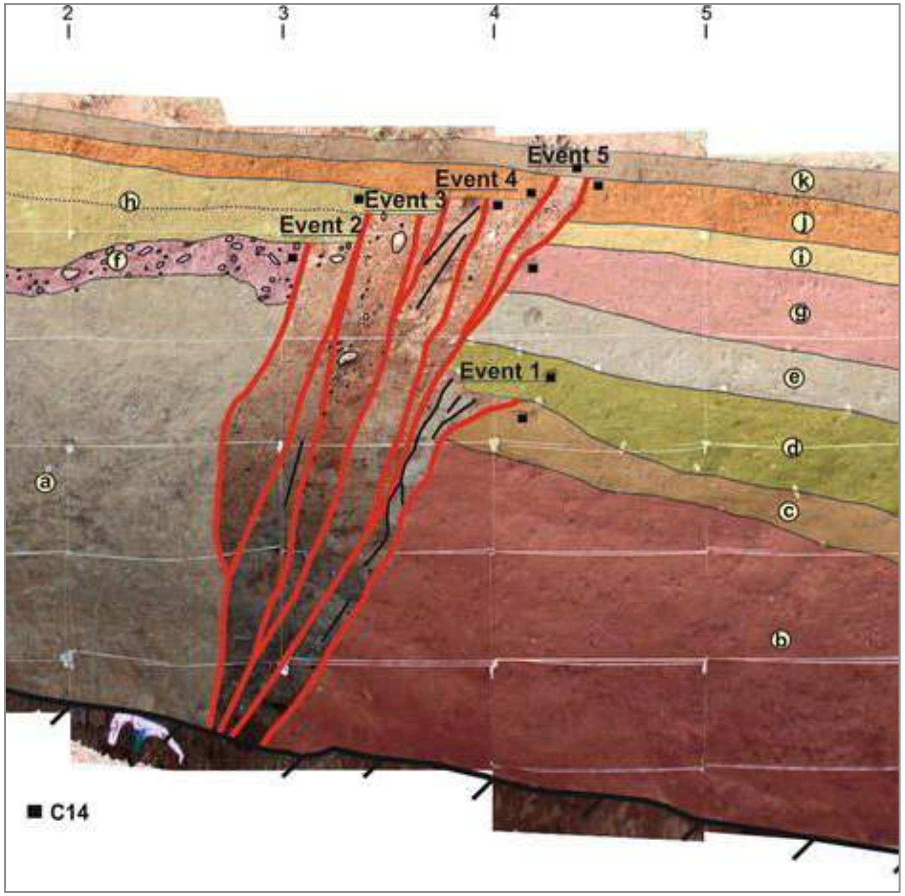
Predictability



The pitch drop experiment was started in 1927 by Prof. T Parnell in Australia, to demonstrate that some “solid” materials are highly viscous fluids.
Since then, 10 drops went down without witnesses at the right moment; pitch droplets fall on average every 110+/-23 months.

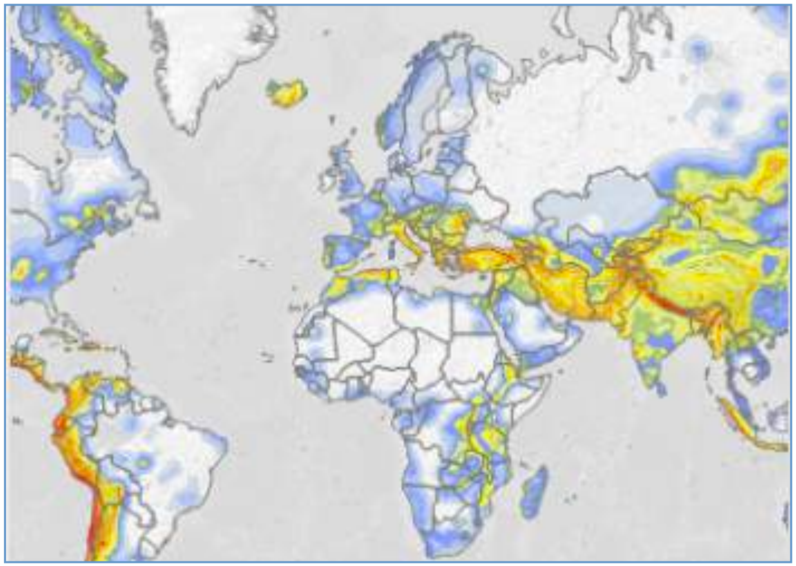
John Mainstone,
IgNobel Prize 2005

Predictability



At best, when a fault source is identified at the surface, and the past earthquakes have left a recognizable geologic record dated with some uncertainties, we can forecast the future events similarly to the pitch drop experiment:
mean recurrence time for most relevant ruptures, and variance of the observations.

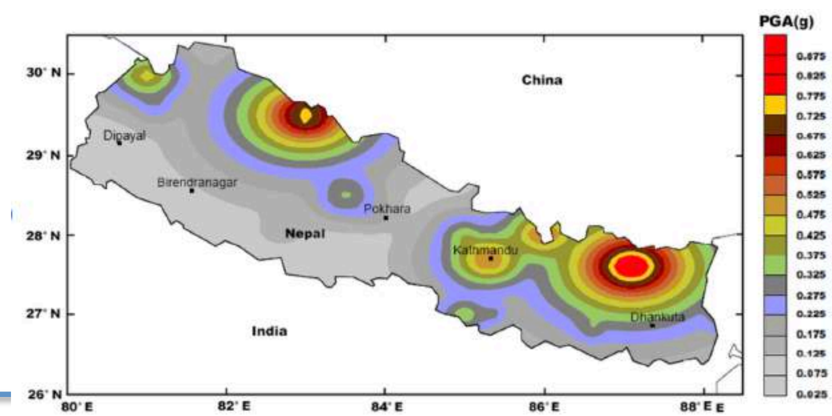
Predictability



Seismic hazard maps answer the questions:

1) WHAT
2) WHERE
3) WHEN*

Probabilistic and Deterministic hazard maps are long-term forecast of the shakings due to earthquakes



Deterministic seismic hazard map for Nepal in terms of mean PGA.

- Consequences of an imprecise/wrong forecast

- Short-term prediction must rely with the time needed for changes that impact on the communities

Sumatra, 26 Dec 2004

2004 Fall Meeting
Search Results

Cite abstracts as **Author(s) (2004), Title, *Eos Trans. AGU*, *85*(47), Fall Meet. Suppl., Abstract xxxxx-xx**

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Indonesia

Paleoseismic studies of corals …the failure of subduction interface … the next sequence may well be no more than a few decades away …

AB: No giant earthquakes have struck the outer-arc islands of western Sumatra since the sequence of 1797, 1833 and 1861. Paleoseismic studies of coral microatolls reveal that failure of the subduction interface occurs in clusters of such earthquakes about every 230 years. Thus, the next such sequence may well be no more than a few decades away. In the meantime, GPS measurements and paleogeodetic observations show that the islands continue to submerge, dragged down by the downgoing oceanic slab, in preparation for the next failures of the subduction interface. Uplift of the islands and seafloor one to two meters during large events leads to large tsunamis and substantial changes in the coastal environments of the islands, including the seaward retreat of fringing reef, beach and mangrove environments. Having spent a decade characterizing the seismic history of western coastal Sumatra, we are now beginning to work with the inhabitants of the islands and the mainland coast to mitigate the associated hazards. Thus far, we have begun to creat and distribute posters and brochures aimed at educating the islanders about their natural tectonic environment and guiding them in preparing for future large earthquakes and tsunamis. We are also installing a continuous GPS network, in order to monitor ongoing strain accumulation and possible transients.
DE: 6605 Education
SC: Public Affairs [PA]
MN: 2004 AGU Fall Meeting

AGU Fall Meeting 2004
San Francisco
13-17 December

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Haiti, 2010

Coulomb stress evolution in Northeastern Caribbean over the past 250 years due to coseismic, postseismic and interseismic deformation

Syed Tabrez Ali[1], Andrew M. Freed[1], Eric Calais[1], David M. Manaker[1,†] and William R. McCann[2]

Article first published online: 22 AUG 2008

DOI: 10.1111/j.1365-246X.2008.03634.x

Issue

Geophysical Journal International

Volume 174, Issue 3, pages 904–918, September 2008

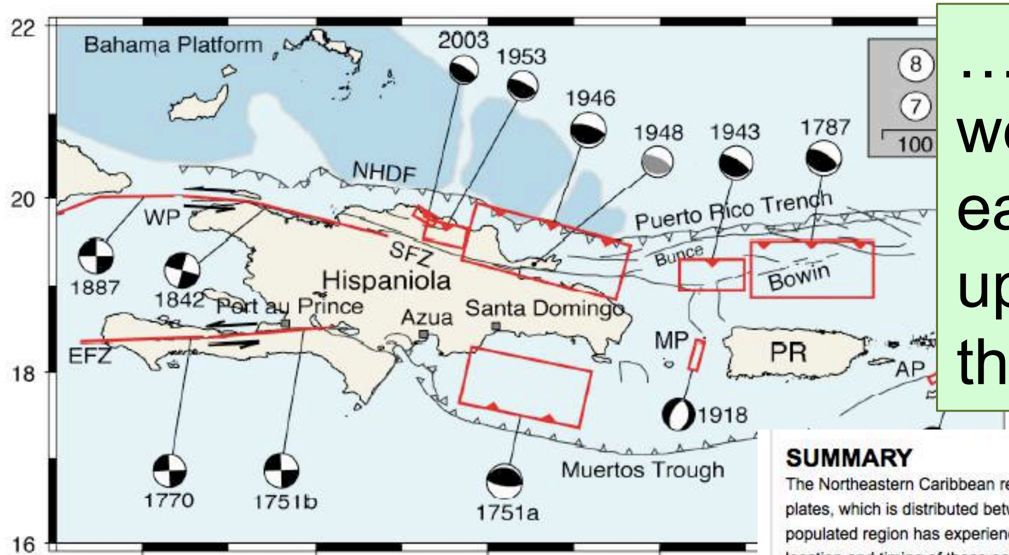
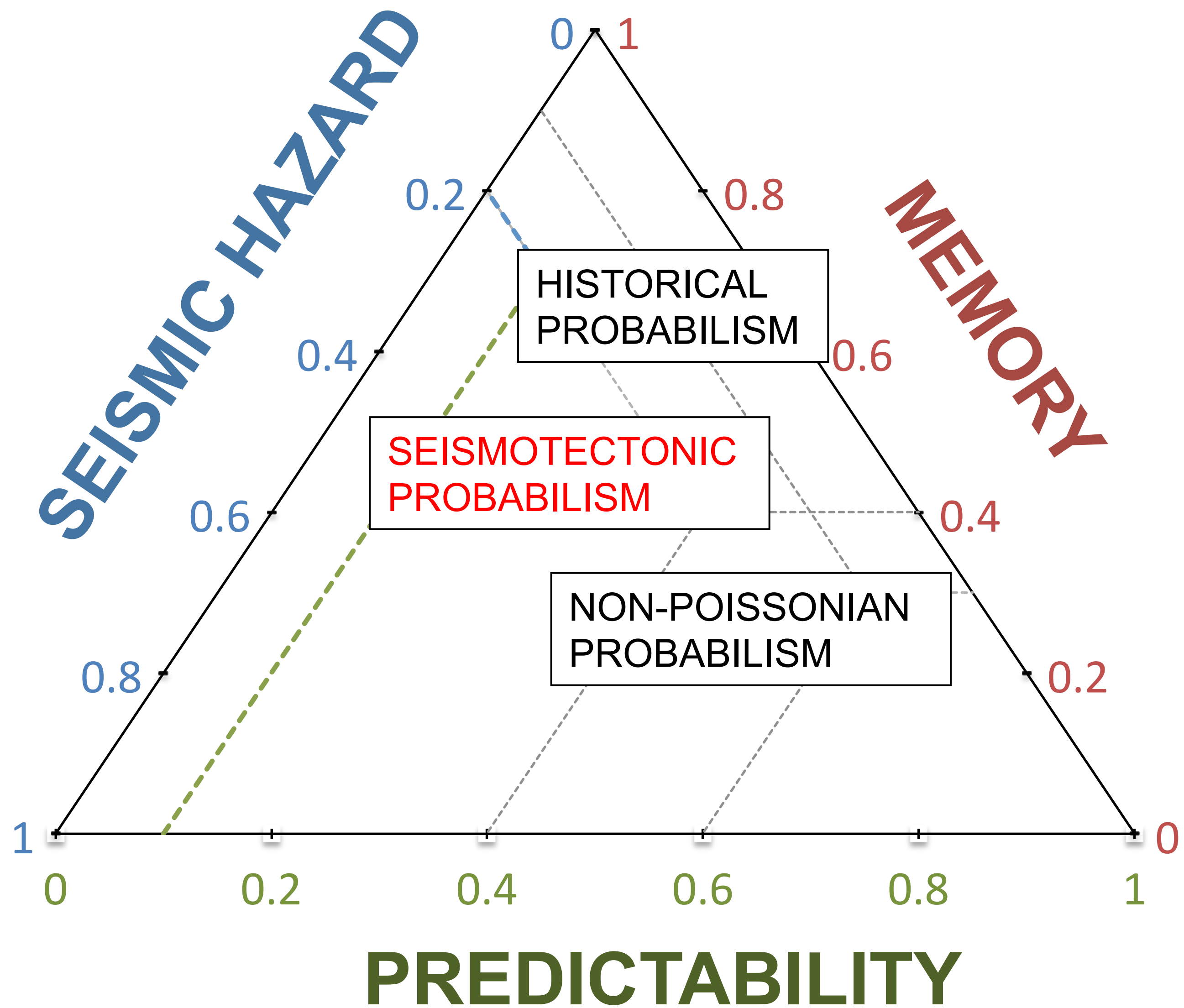


FIG. 1.1: Carte des séismes historiques et récents dans le nord-est Caraïbe. Le zones de rupture sismiques estimées. Les symboles indiquent le type de mouv ces séismes.

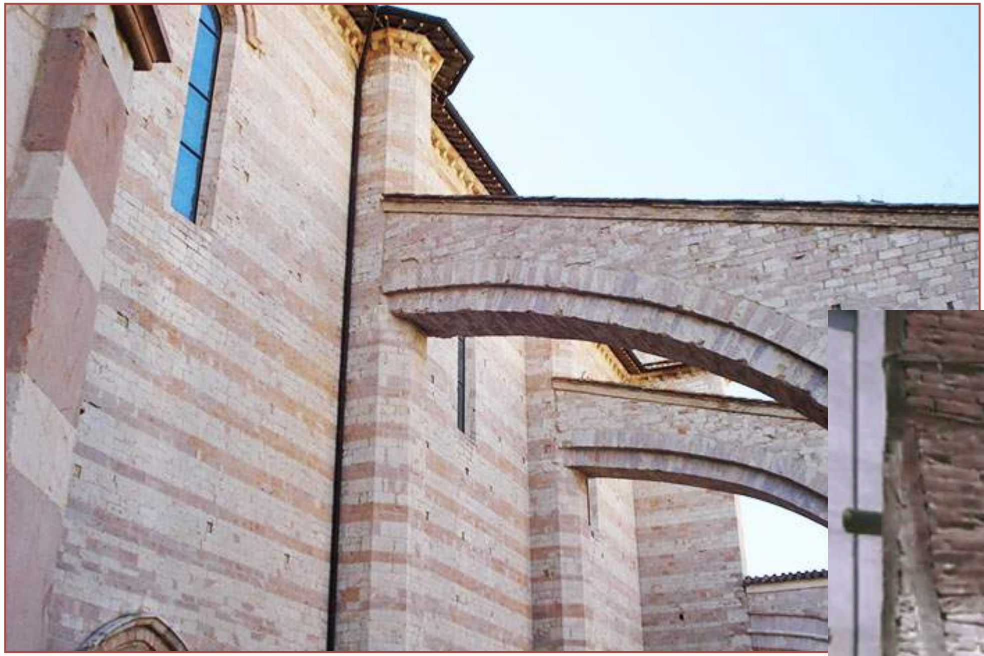
…we observed progressive westwards propagation of earthquakes… net stress build up over the past 250 years is the largest west of 70°.5 W …

SUMMARY

The Northeastern Caribbean region accommodates ~20 mm yr^{-1} of oblique convergence between the North American and Caribbean plates, which is distributed between the subduction interface and major strike-slip faults within the overriding plate. As a result, this heavily populated region has experienced eleven large ($M \geq 7.0$) earthquakes over the past 250 yr. In an effort to improve our understanding of the location and timing of these earthquakes, with an eye to understand where current seismic hazards may be greatest, we calculate the evolution of Coulomb stress on the major faults since 1751 due to coseismic, postseismic, and interseismic deformation. Our results quantify how earthquakes serve to relieve stress accumulated due to interseismic loading and how fault systems communicate with each other, serving both to advance or retard subsequent events. We find that the observed progressive westwards propagation of earthquakes on the Septentrional and Enriquillo strike-slip faults and along the megathrust was encouraged by coseismic stress changes associated with prior earthquakes. For the strike-slip faults, the loading of adjacent segments was further amplified by postseismic relaxation of a viscoelastic mantle in the decades following each event. Furthermore, earthquakes on the Septentrional fault relieve a small level of Coulomb stress on the parallel Enriquillo fault to the south (and vice versa), perhaps explaining anticorrelated timing of events on these respective fault systems. The greatest net build-up of Coulomb stress changes over the past 250 yr occurs along the central and eastern segment of the Septentrional and the Bowin strike-slip faults (65°–71°W), as no recent earthquake has relieved stress in these regions. For oblique thrust faults, net stress build-up over the past 250 yr is the largest on the North American/Caribbean megathrust west of 70.5°W. High Coulomb stress has also developed east of 65.5°W, where no historic events have been inferred to have relieved stress, though uncertainties in fault slip rates from our block model associated with a lack of GPS observations in this region may have led to an over-estimation of stress changes.


SEISMIC HAZARD
MEMORY
PREDICTABILITY
0
1
0.2
0.8
0.4
0.6
0.6
0.4
0.8
0.2
1
0
0
0.2
0.4
0.6
0.8
1
HISTORICAL PROBABILISM
SEISMOTECTONIC PROBABILISM
NON-POISSONIAN PROBABILISM

Memory



Flying buttresses
Assisi, Central Italy

Traditional buildings
Golcuk, Turkey

Memory

Traditional buildings
Golcuk, Turkey

Memory = Awareness

Alfama, Lisbon August 2015

Venzone, Italy Permanent Exhibition on 1976 earthquakes, Special labs for the 40 anniversary

Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS

What do youths think 40 years after a strong earthquake

581* students

422 surveys

57% 10 - 15 years old

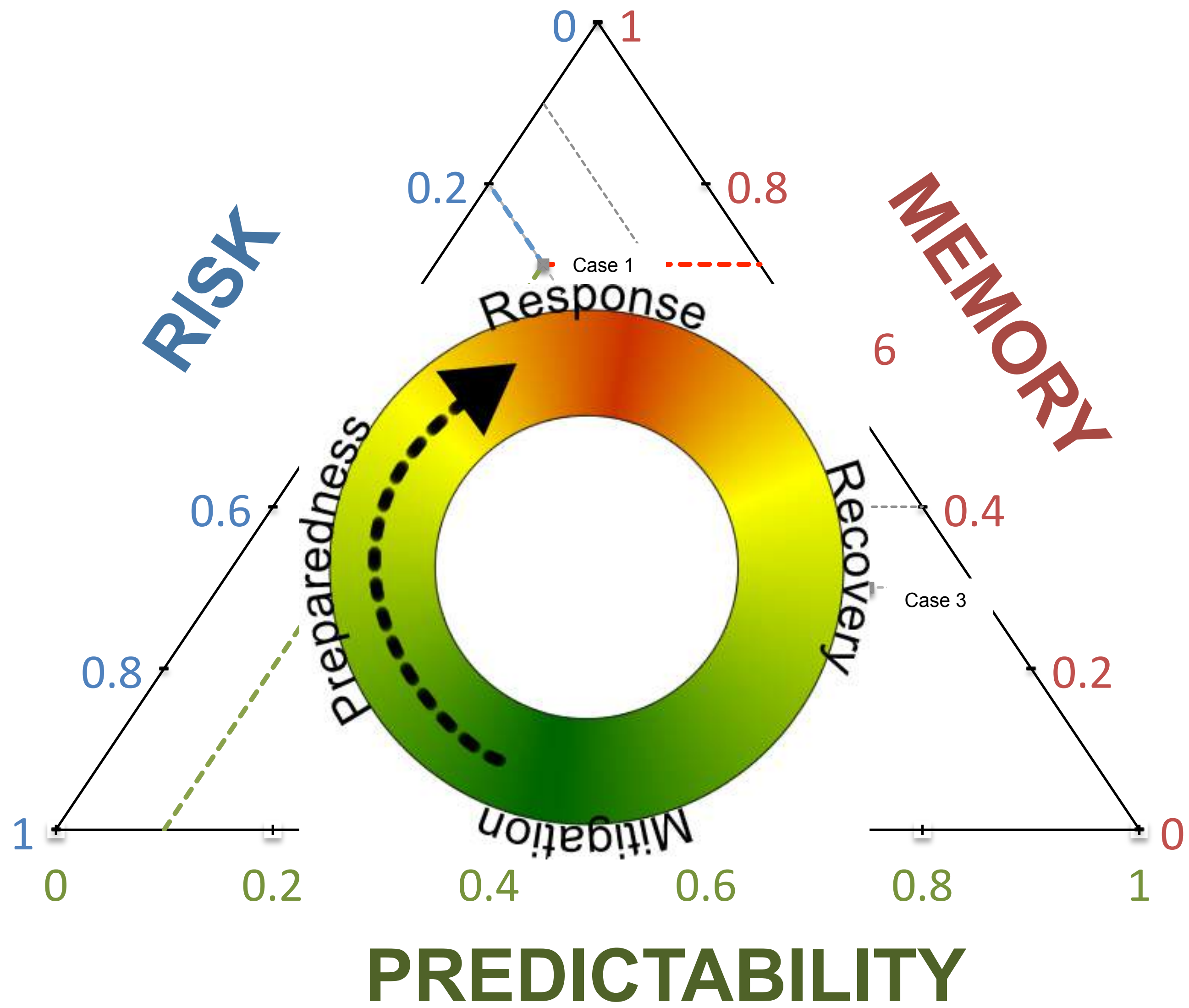
What's the main natural hazard in your municipality?

Landslides	Floods	Tsunami	Earthquakes
22%	16%	4%	52%

Facts about 1976

1) Where — 11%
2) How long — 13%
3) Deaths — 35%

Transition toward preparedness



Grazie!

lperuzza@inogs.it