

Engineering Seismology and Seismic Hazard – 2019

Lecture 2

# Earthquake Hazard and Risk

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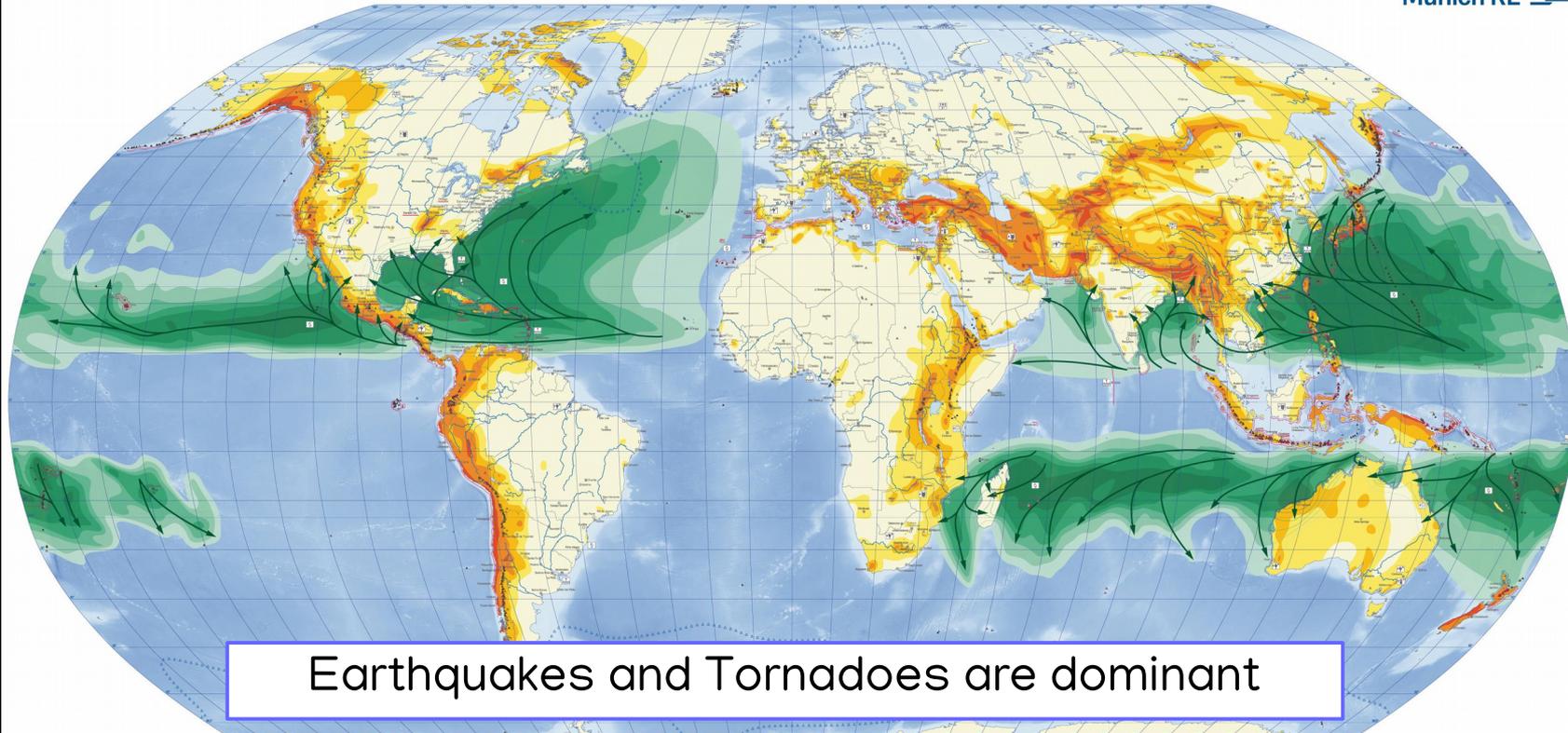
National Institute of Oceanography and Applied Geophysics (OGS)



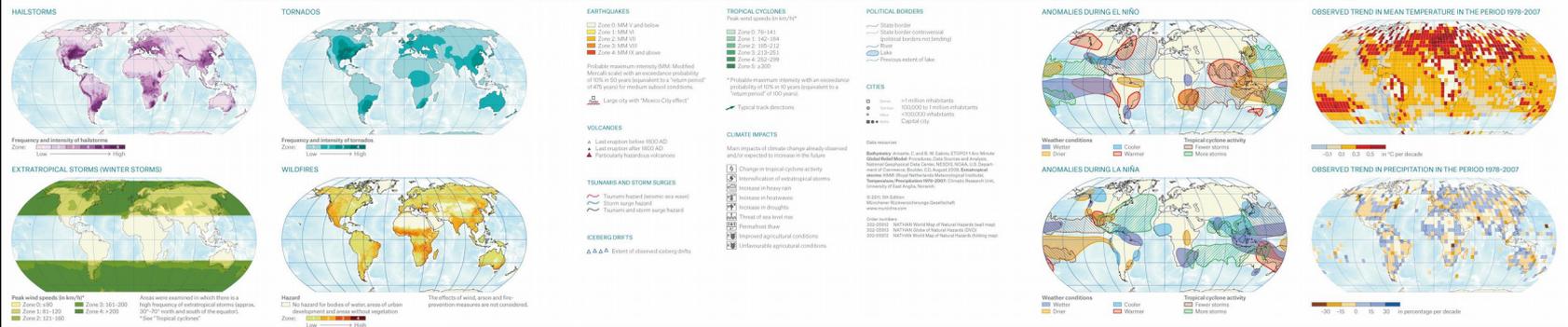
# Natural Hazards

NATHAN WORLD MAP OF NATURAL HAZARDS

Munich RE 

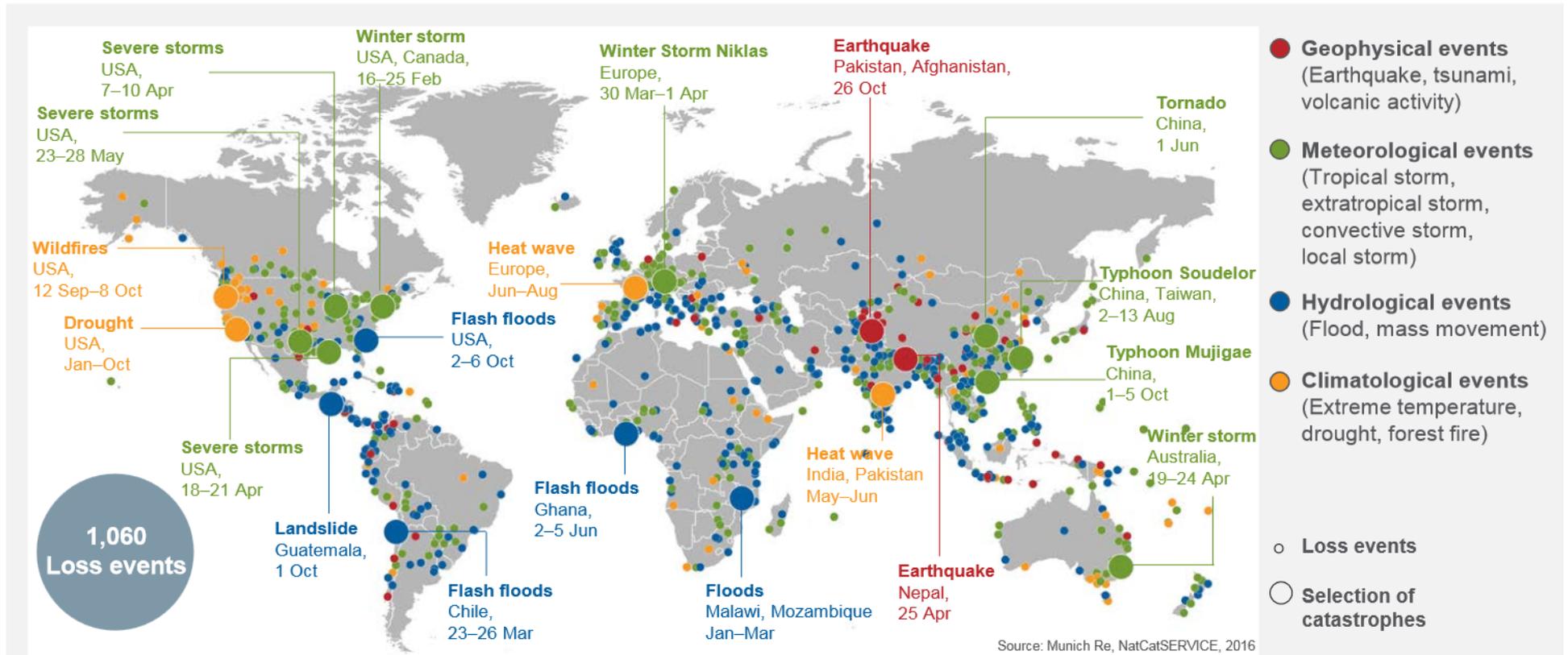


Earthquakes and Tornadoes are dominant



# Global Losses

## Natural loss events worldwide 2015 Geographical overview



The United Nations estimates natural disasters and hazards in the past 20 years have affected four billion people, claiming 1.3 million lives, with a cost of around two trillion dollars in economic losses.

# Earthquake Hazard

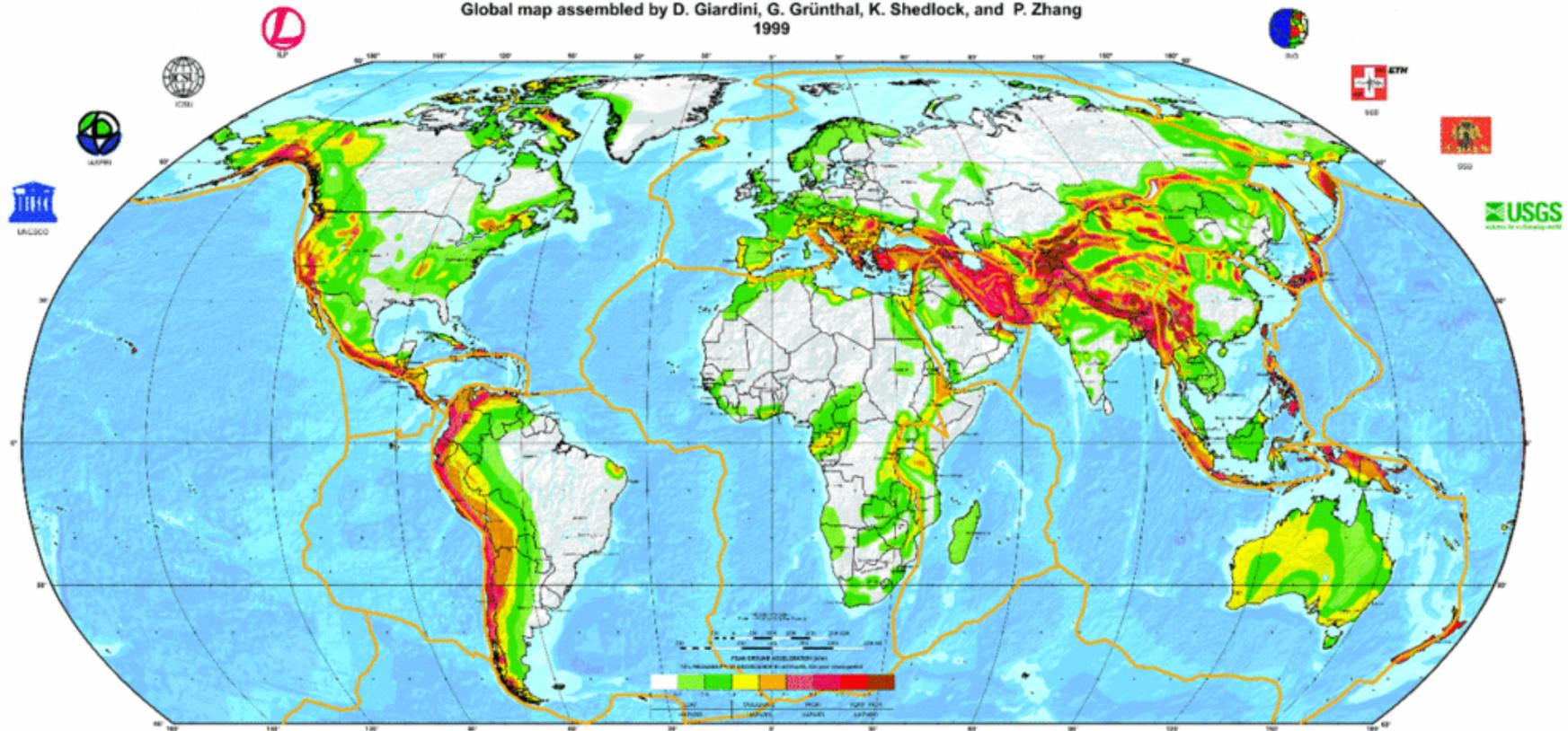
## GLOBAL SEISMIC HAZARD MAP

Produced by the Global Seismic Hazard Assessment Program (GSHAP),  
a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the  
International Lithosphere Program.

**GFZ**  
POTSDAM

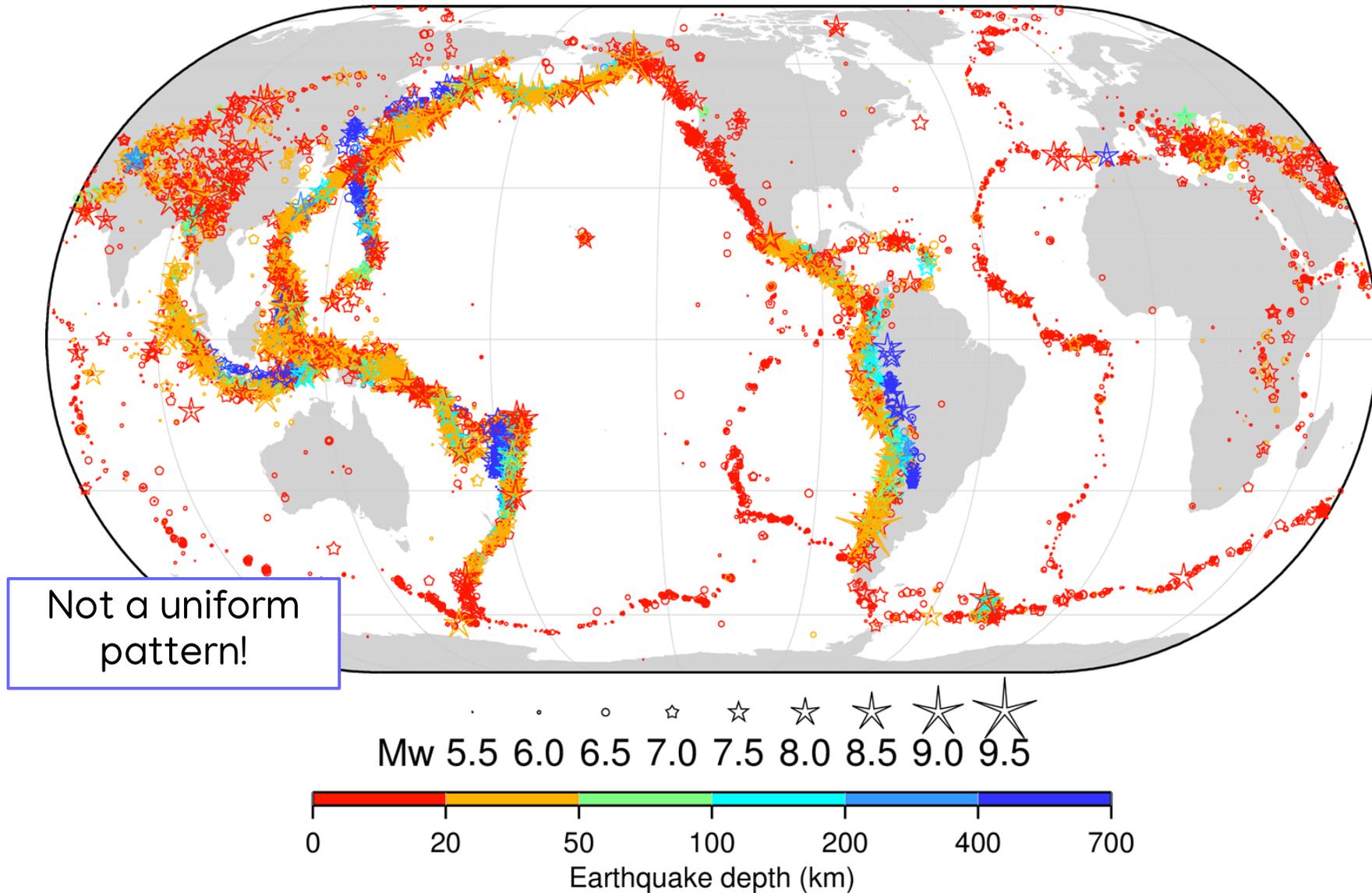
International Decade for Natural Disaster Reduction  
**IDNDR**  
1990 - 2000  
Building a Culture of Prevention

Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang  
1999



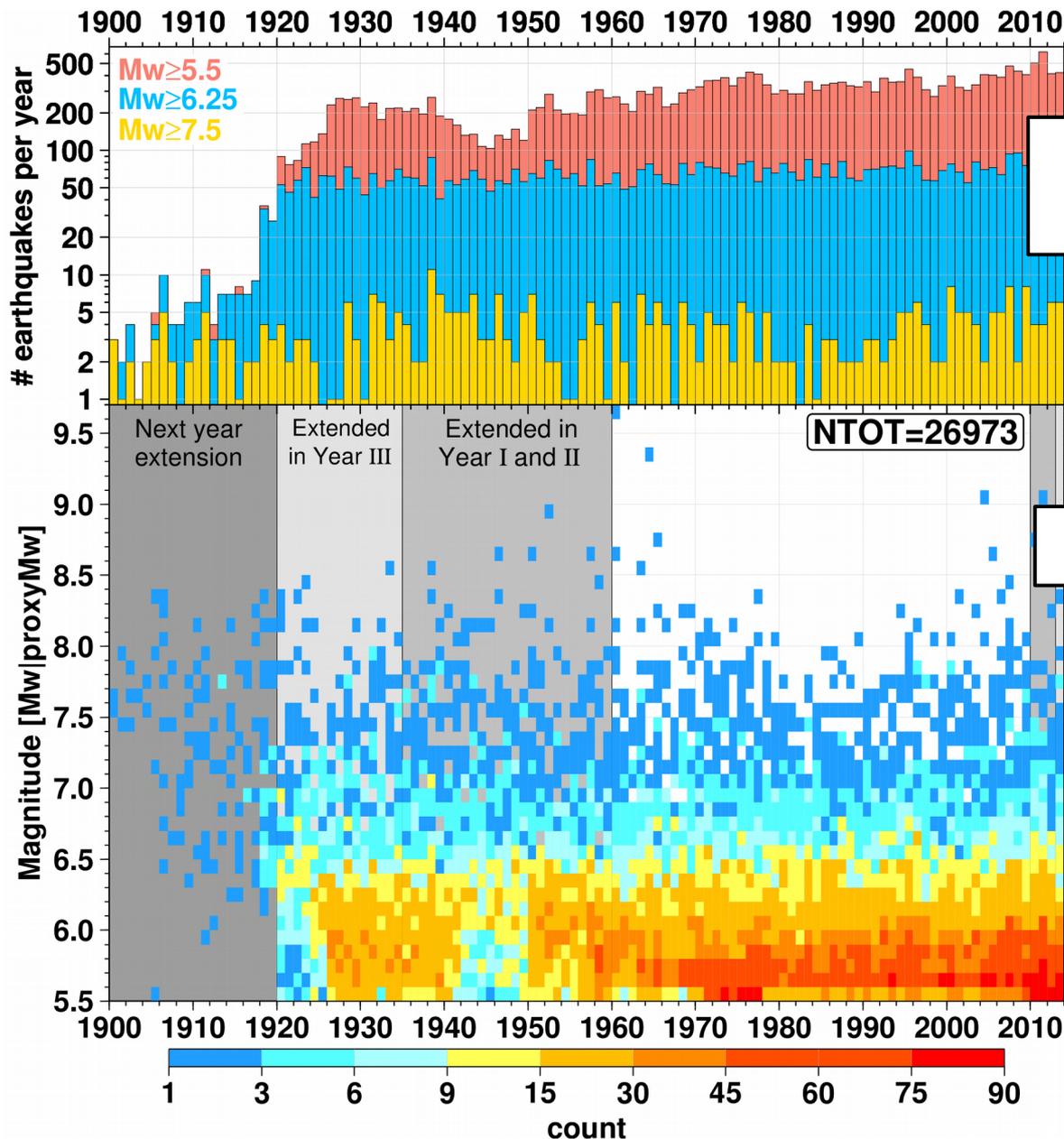
60% of the world population lives in countries with a significant seismic hazard

# Where do Earthquakes Occur?



90% most of the worlds seismicity occurs long the Ring of Fire

# How often do Earthquakes occur?



Do earthquakes occur uniformly in time?

Why gaps in the record?

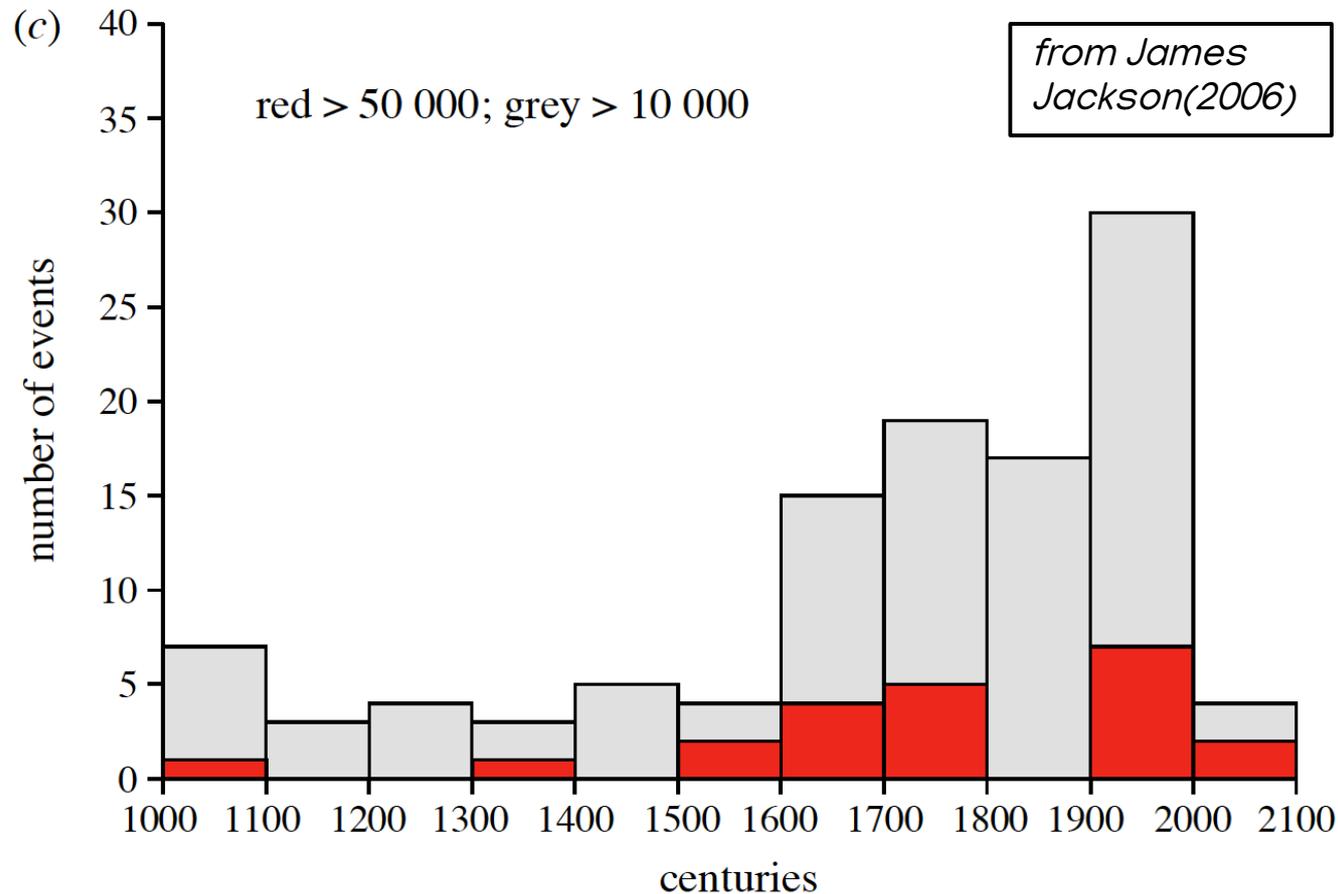
<http://www.isc.ac.uk/>

# Occurrence in Numbers

Earthquakes occur actually quite often (more than we expect)  
However, large magnitude earthquakes are rather infrequent.

Magnitude	Description	Number in 1 Year	One Quake Every
8+	Great	< 1	1--2 years
7.0-7.9	Major	17	every 20days
6.0-6.9	Large	135	3 days
5.0-5.9	Strong	1320	9 hours
4.0-4.9	Moderate	13000	90 minutes
3.0-3.9	Mild	130000	11 minutes
2.0-2.9	Small	1300000	2 minutes

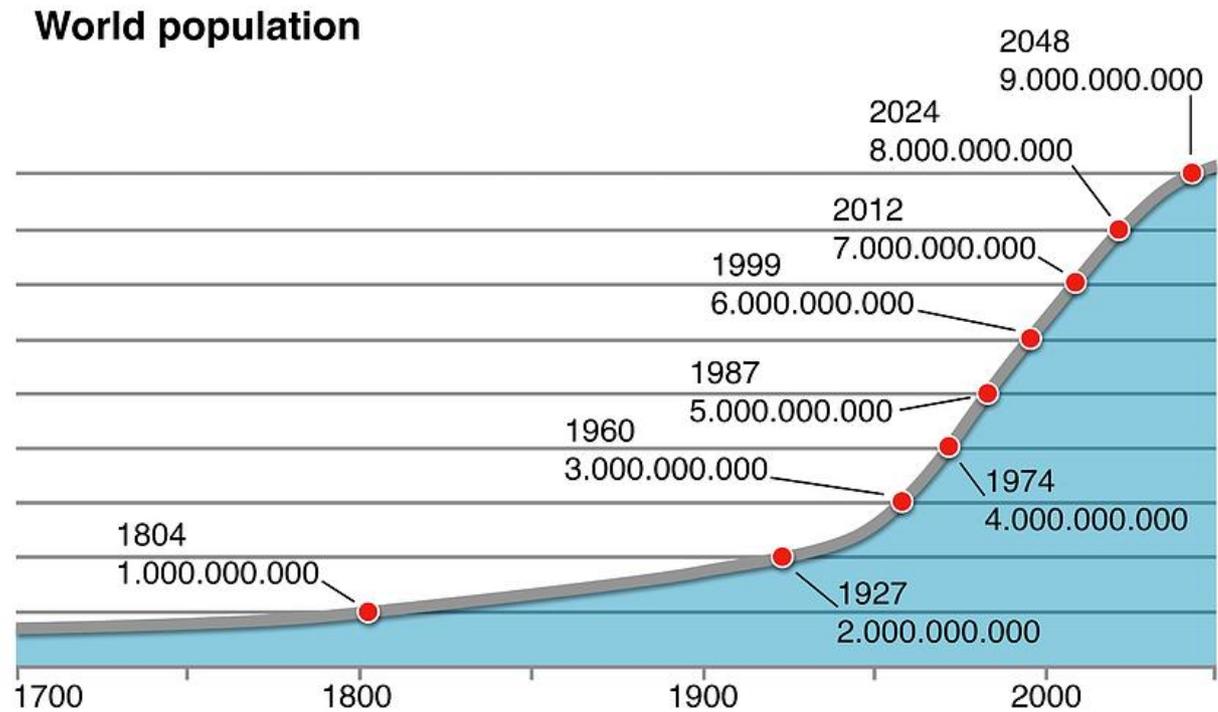
# Impact of Earthquakes over Time



Histogram of the number of earthquakes killing more than 10000 (grey) or 50000 (red) people per century.

# World population growth

*“The global population distribution is changing rapidly as underdeveloped nations continue to grow most rapidly in cities that are preferentially located in seismically hazardous regions.” (Bilham, 2004, Allan et al 2007).*



Increased population: **increased earthquake risk**

Consequences:

- Number of people killed in earthquakes continues to rise in poorer nations
- Cost of earthquakes continues to rise for rich nations

# Destructive Earthquakes



Earthquakes around the world

## VALDIVIA EARTHQUAKE

**MAY 22 1960**  
Most powerful earthquake on record, comparable to **1,000 atomic bombs** detonating at once

**9.5 magnitude**

**\$1 billion** in damage

Valdivia, Chile

Triggered tsunamis in Hawaii and Japan

**6,000** Deaths  
**165,000** Injured  
**20,000** Homeless

© MapsofWorld 2014

YEAR	LOCATION	MAGNITUDE	ESTIMATED DEATH TOLL
<b>1</b>	1976 Tangshan, China	7.5	255,000
<b>2</b>	1920 Gansu, China	8.6	200,000
<b>3</b>	1927 Qinghai, China	7.9	200,000
<b>4</b>	1923 Kanto, Japan	7.9	143,000
<b>5</b>	1948 Turkmenistan	7.3	110,000
<b>6</b>	1908 Messina, Italy	7.2	70,000
<b>7</b>	1932 Gansu, China	7.6	70,000
<b>8</b>	1970 Peru	7.9	66,000
<b>9</b>	1990 Iran	7.7	40,000
<b>10</b>	1935 Quetta, Pakistan	7.5	30,000

SOURCES: United States Geological Survey, Associated Press

THE WASHINGTON POST

However, earthquakes of similar size (and energy) do not often produce comparable effects and consequences

# Earthquake Risk Controlling Factors

Earthquake Risk

=

Seismic Hazard \* Vulnerability \* Exposure

Natural:

- Strength of Earthquake
- Distance from earthquake epicentre
- Earthquake depth
- Ground type (Soft Soil)
- Duration

Anthropic:

- Population density
- Quality of building construction and design
- Level of development
- Level of population preparedness
- Time of disaster

# To Remember!

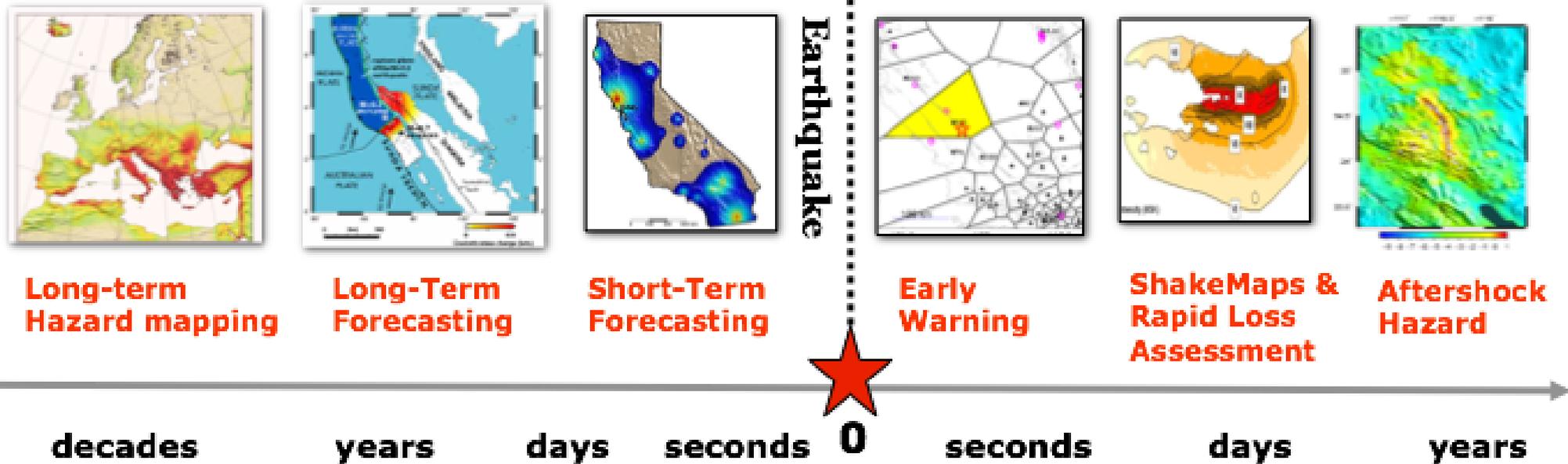
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"Earthquakes don't kill people, collapsed buildings do so"

# Hazard Mitigation Strategies

From the past

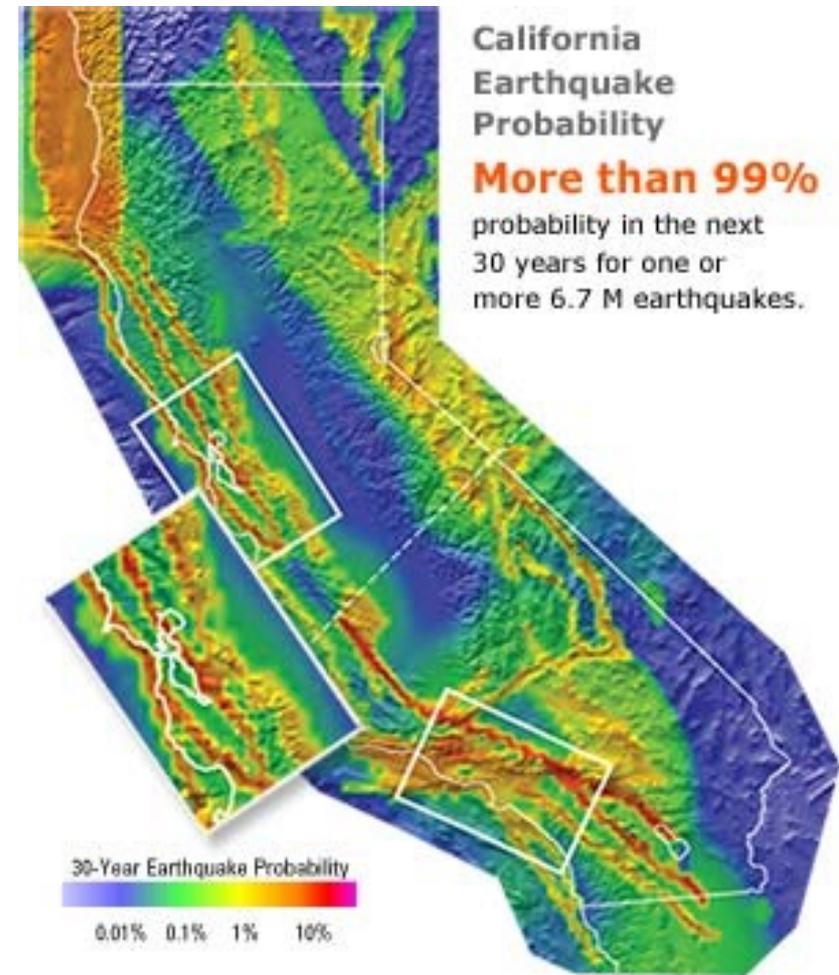
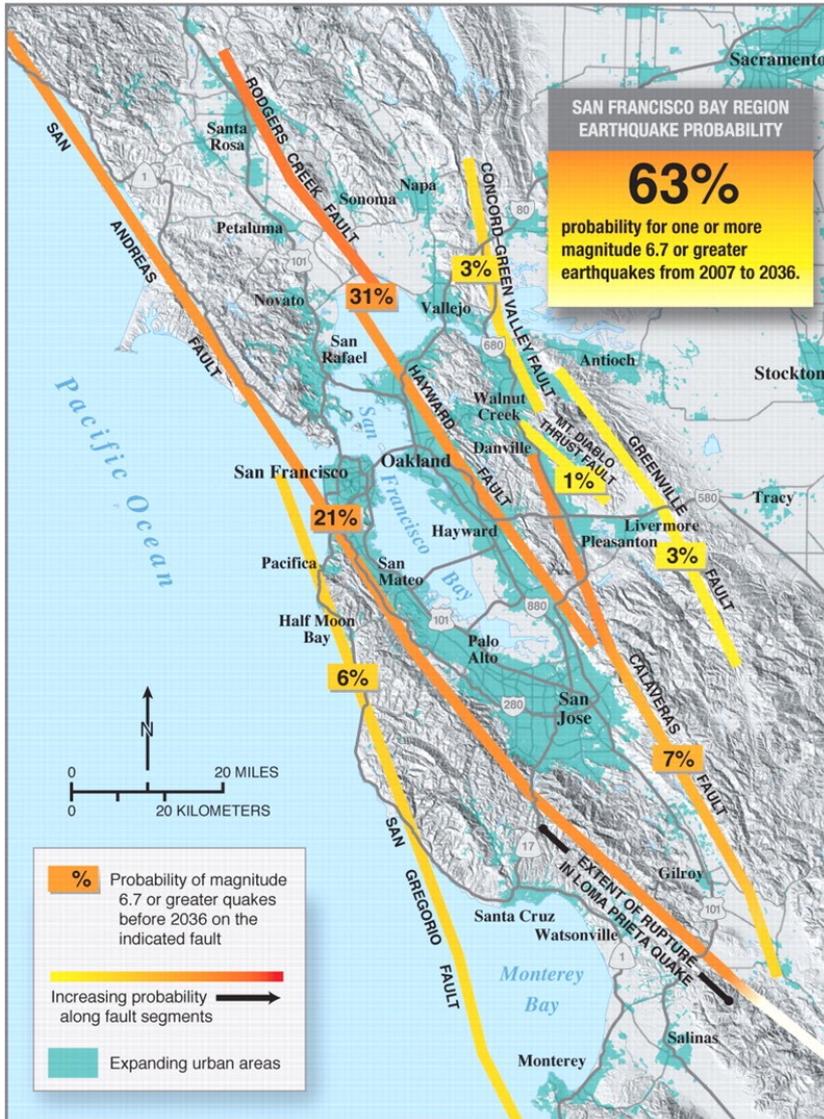
To the future



TO REMEMBER: Earthquakes cannot be predicted (so far)!



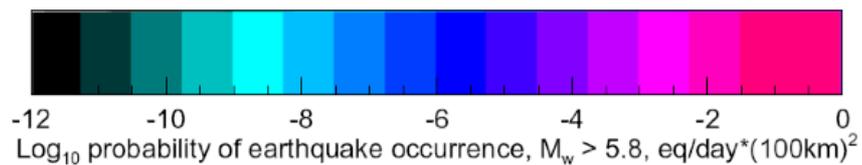
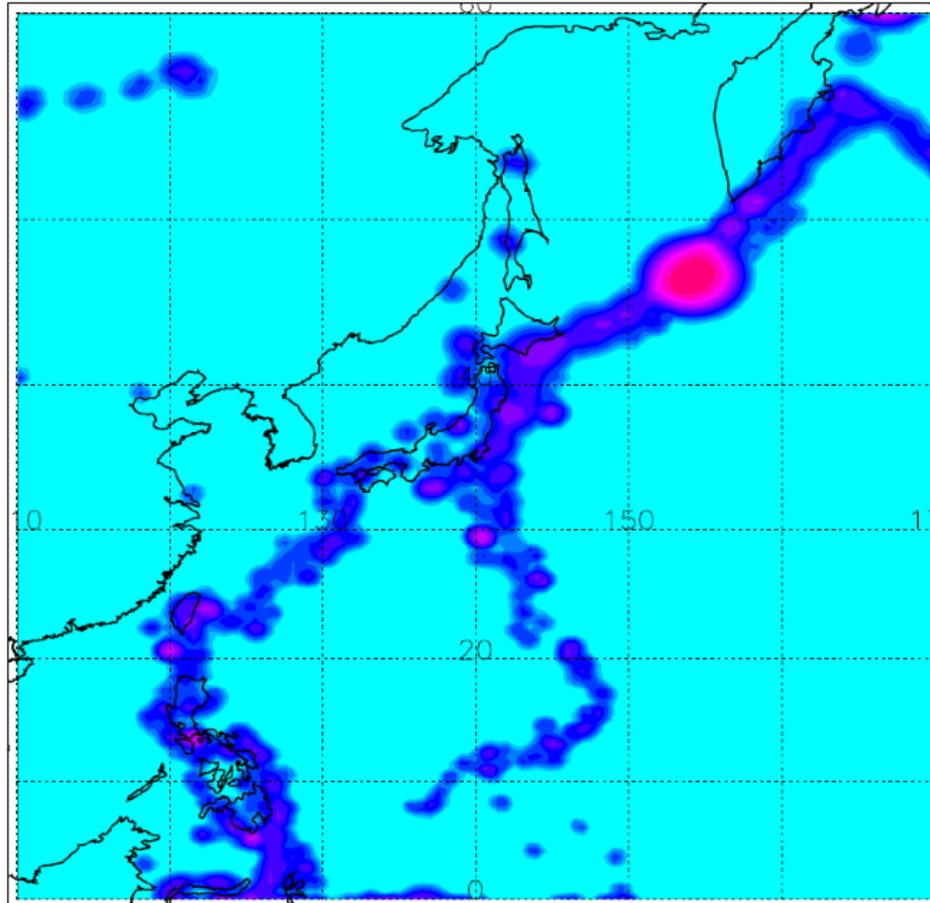
# Long-Term Forecasting



# Short-Term Forecast

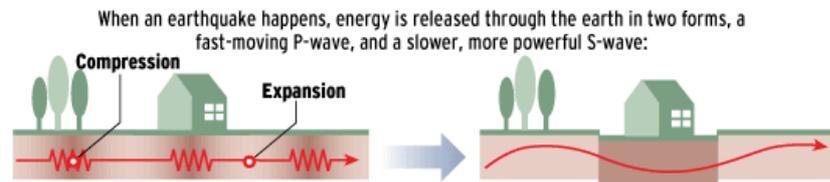
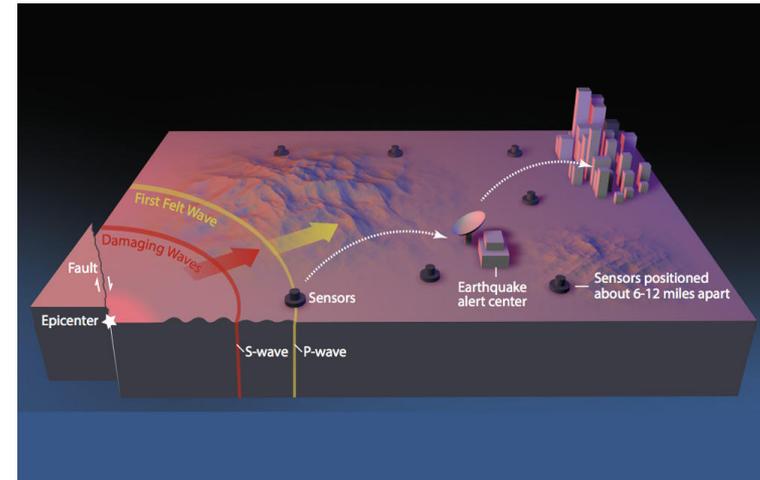
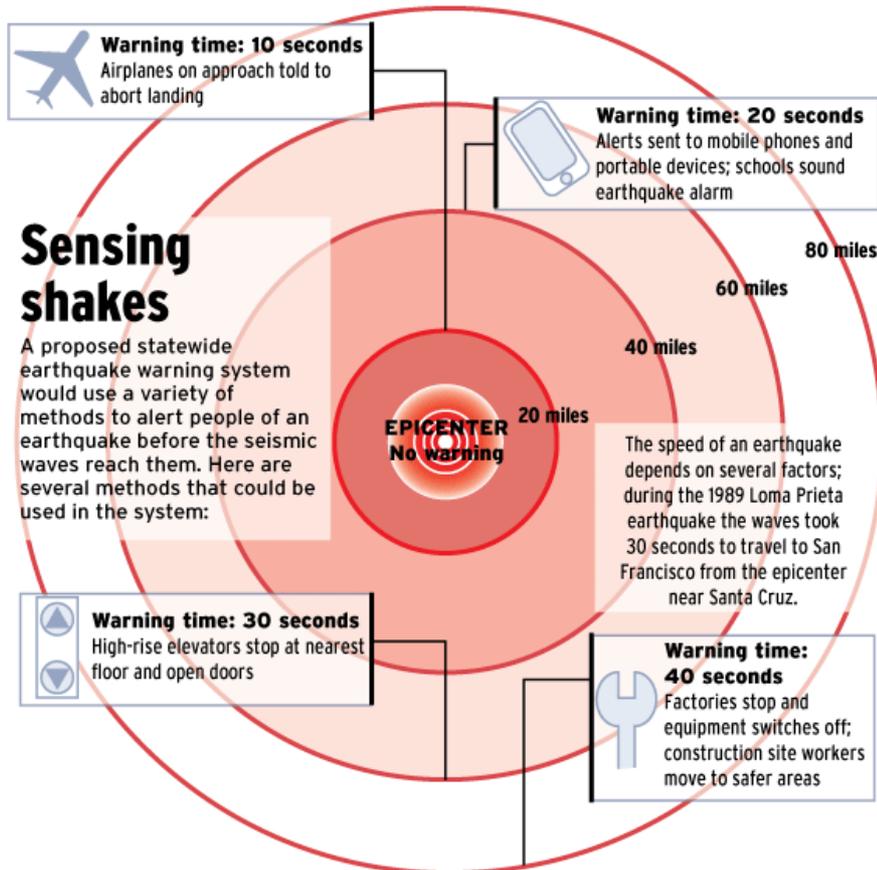
Wed Nov 15 23:51:41 2006

Northwest Pacific short-term forecast: 1977-Today



Forecast one day after  
the recent (2006/11/15)  
M8.3 Kuril Islands  
earthquake.

# Early Warning Systems



**P-wave**  
A P- (or compressional) wave compresses and expands the earth as it moves. P-waves move fast, but don't cause much damage.

**S-wave**  
An S- (or shear) wave physically moves the earth like an ocean wave as it moves. S-waves carry more of the quake's energy.

Sources: Scientific American; United States Geological Service

The Register

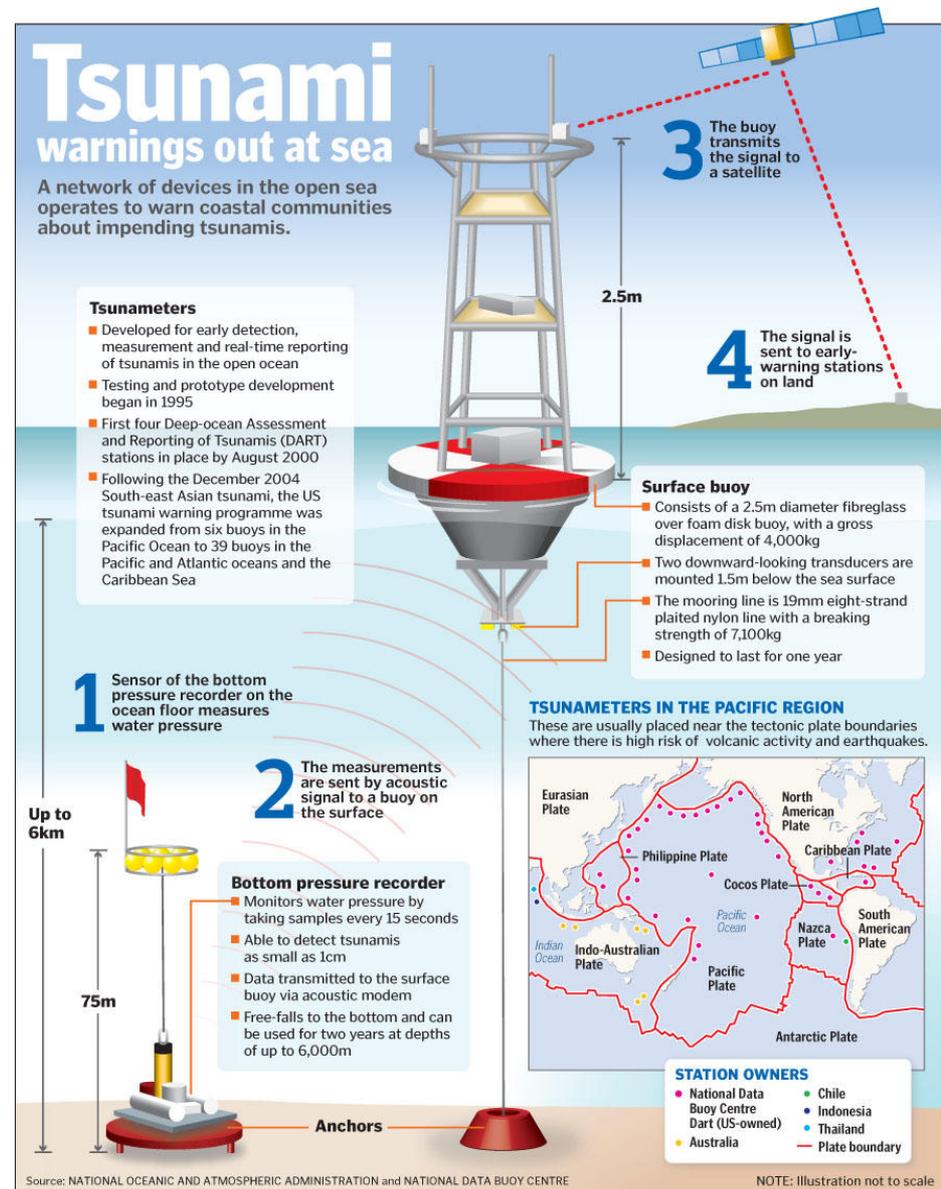


## On your screen: ShakeAlert

- 1 Real-time tracking of seismic waves from quake's epicenter.
- 2 Real-time tracking of the fault rupture (updates intensity).
- 3 Your current location tracked by GPS.
- 4 Seconds remaining before seismic waves reach you.
- 5 Expected intensity of quake at your current location.
- 6 Estimated magnitude of quake.
- 7 Intensity scale.

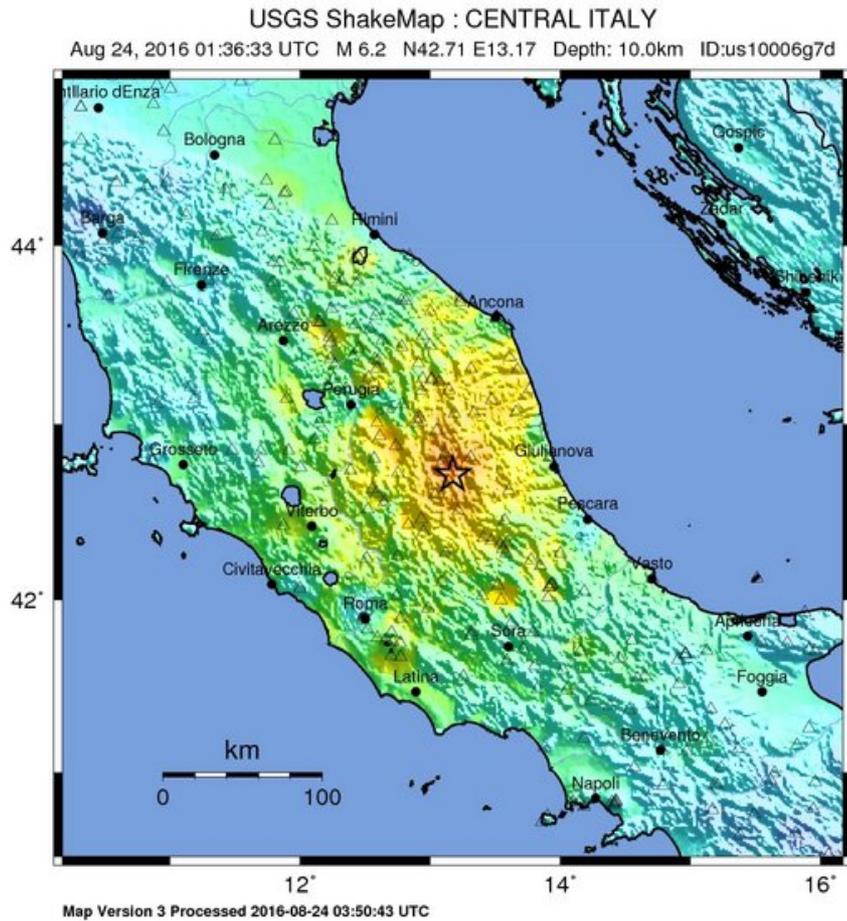
# Early Warning Systems

The most difficult situations arise in areas located close to active offshore faults, where tsunamis arrive so quickly that there is no time for a warning.



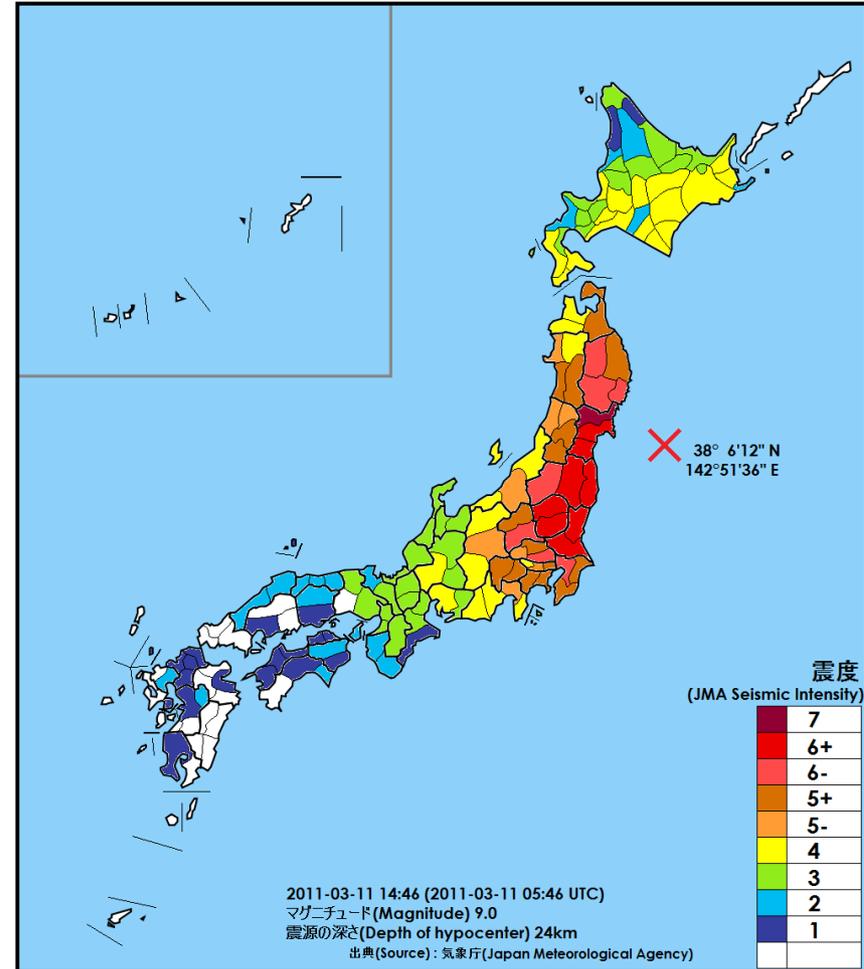
# Shake Maps

## 2016 Norcia Earthquake, Italy



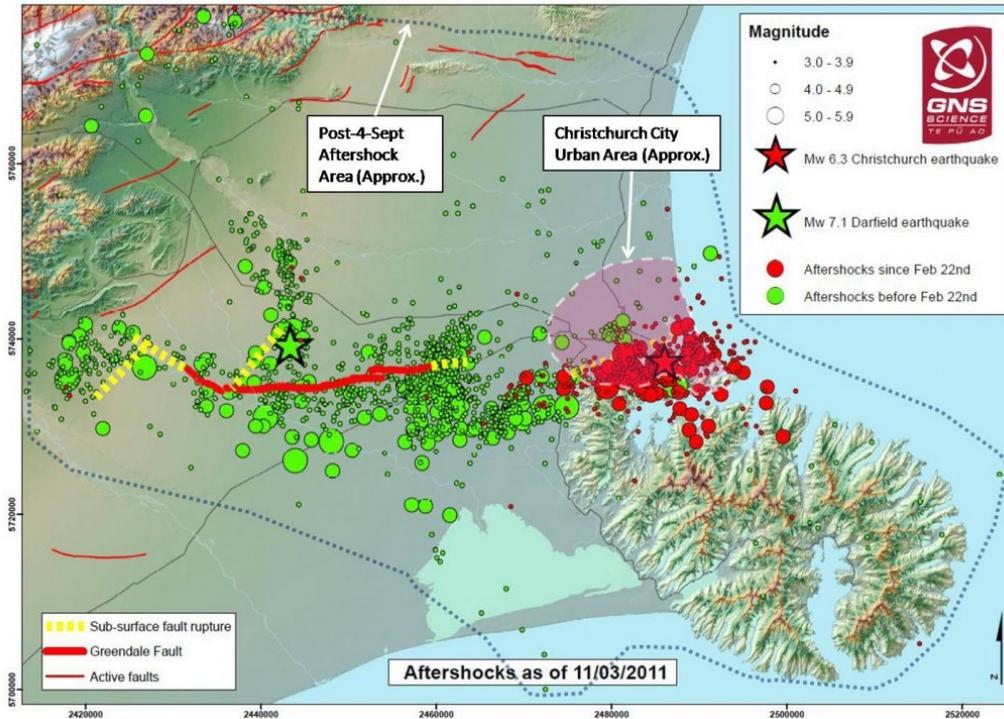
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.06	0.2	0.8	2.0	4.8	12	29	70	>171
PEAK VEL.(cm/s)	<0.02	0.08	0.3	0.9	2.4	6.4	17	45	>120
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Fraenza and Michelini, 2010, 2011

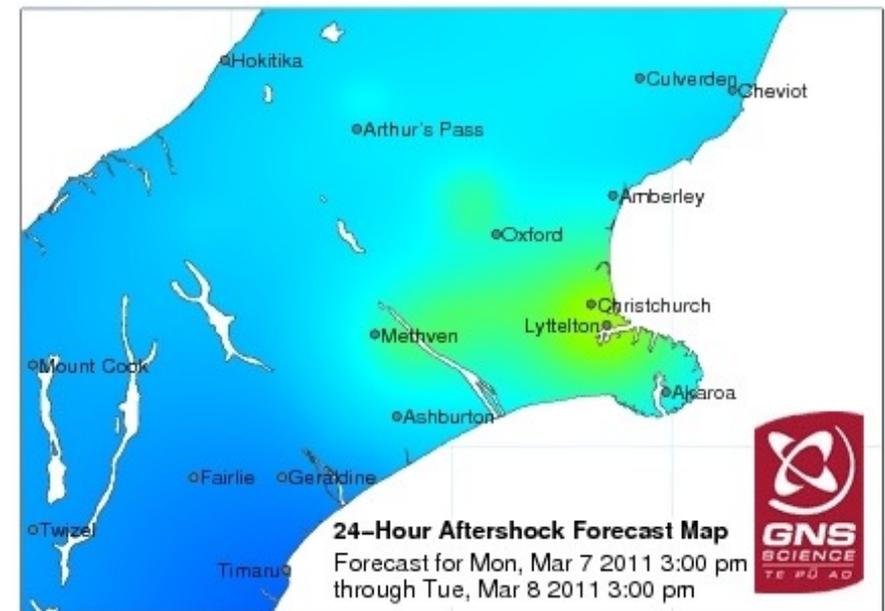


## 2011 Tohoku Earthquake, Japan

# Aftershock Hazard



2011 Christchurch Earthquake, New Zealand



# Course Message

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Earthquake is a complex phenomenon and no hazard mitigation strategy can be put in place without an appropriate understanding of its generation and propagation mechanism.

Therefore, the course will focus on the main theoretical and applicative aspects of seismology, with the goal of providing you with the necessary knowledge to critically and independently handle the most common problems in the seismic engineering practice.

However, since our scientific comprehension of the earthquake phenomenon is “relatively” limited, we will particularly focus on the concept of **uncertainty** and the way this is handled in seismic hazard analysis...

# Resources

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These lectures wouldn't have been available without the contribution of many people and the numerous resources from textbooks and online material (see attached file for a complete list)

A special acknowledgment (and a personal thanks) goes to the following people for their supporting material:

Dr. Dario Slejko – OGS, Trieste, Italy

Dr. Laurentiu Danciu – Swiss Seismological Service, ETH, Zurich, Switzerland

Dr. Donat Faeh – Swiss Seismological Service, ETH, Zurich, Switzerland

Dr. Elisa Zuccolo – EUCENTRE Pavia

Dr. John Douglas

Dr. Dave Boore