# Mapping global earthquake hazard and risk

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ETH Zurich, IASPEI President

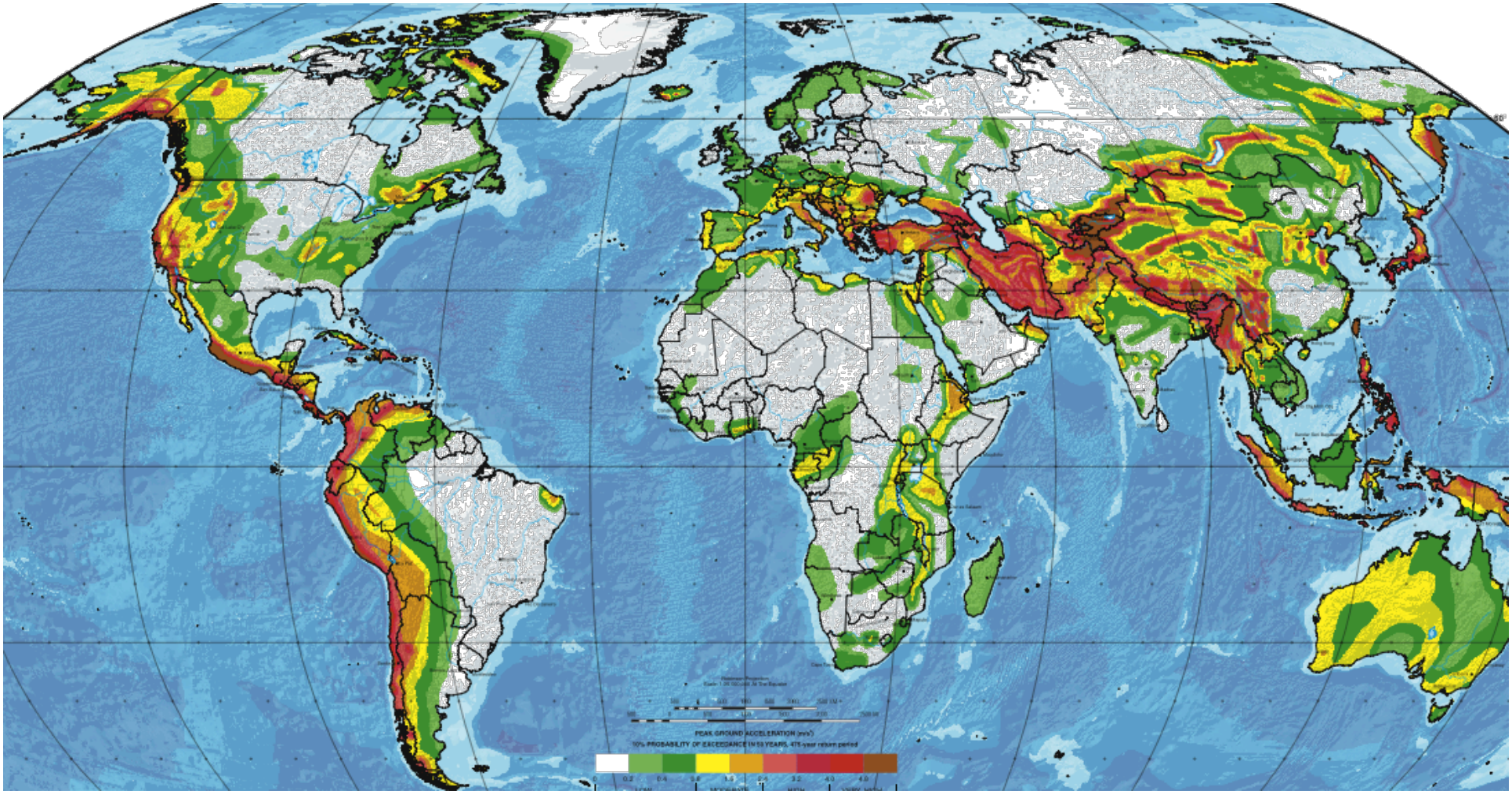
IAHS – IAPSO – IASPEI Joint General Assembly

Gothenburg, July 22, 2013

SHARE

GEM

# GSHAP (2000)




GEM

# GEM in pills

- ✓ Preparation for GEM was initiated by the OECD in 2007; the first 5-yr implementation phase started in 2009
- ✓ A true PPP, with private and public participants, and associate organizations
- ✓ Managed by the GEM Foundation in Pavia
- ✓ Comprehensive assessment of earthquake hazard, vulnerability, risk and socio-economic consequences
- ✓ Three pillars:
  - Global Components
  - Regional Programs
  - GEM Model Facility and OpenQuake

GEM

# GEM today

## GEM

**25+ public and private organisations** sustaining the effort

**15+ regional collaborations** and partnerships with individuals from 100+ organisations for joint model, data and application development, testing and use

**300+ leading experts** from 75+ organisations developing global best practice, datasets and tools

## application

**65+ countries** where the **OpenQuake Engine** has been used (open and transparent software for hazard & risk modelling)

**100+ datasets, tools, models, results** & **apps** that will become available in the OpenQuake Platform after 2014

**25+ workshops and trainings** for technology transfer worldwide

GEM

# GEM Associate Participants

| | |
|---|---|
| **OECD** | Organization for Economic Cooperation and Development |
| **WORLD BANK** | The World Bank |
| **UN-ISDR** | United Nations International Strategy for Disaster Risk Reduction |
| **UNESCO** | United Nations Educational, Scientific and Cultural Organization |
| **IASPEI** | International Association of Seismology and Physics of the Earth's Interior |
| **IAEE** | International Association of Earthquake Engineering |
| IStructE | The Institution of Structural Engineers |
| **EERI** | Earthquake Engineering Research Institute |
| **CSSC** | California Seismic Safety Commission |
| **ICSU/IRDR** | International Council for Science / Integrated Research for Disaster Risk |

GEM

# Role of IASPEI in GEM

- ✓ IASPEI was instrumental in designing the priorities and plans for GEM
- ✓ IASPEI has been an Associate Participant since the beginning
- ✓ Seismologists and scientists working in GEM are IASPEI scientists, and we should take pride and ownership
- ✓ IASPEI commissions will review the GEM products, to provide input for the next iteration of the Global Components
- ✓ GEM supports the creation of new global standards, which fit well the mandate of IASPEI and will be used in the IASPEI community

GEM

# GEM's GLOBAL DATASETS, a €10M investment

## Hazard
*(faulting & shaking)*

- Instrumental quakes
- Active faults
- Historical quakes
- Strain rate
- Ground motion prediction equations

## Exposure and Vulnerability
*(deaths, damage, dollars)*

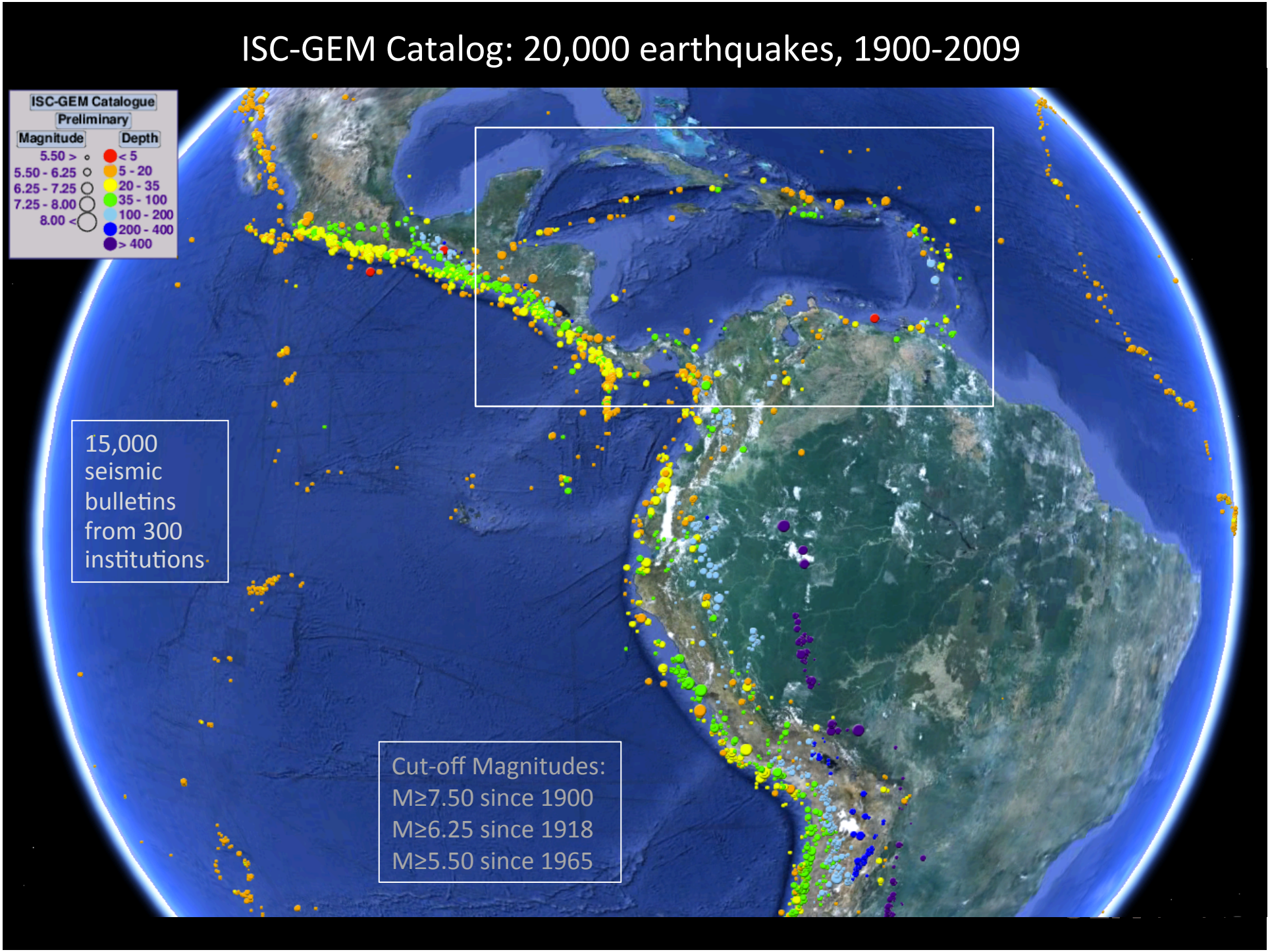
- Exposure
  - Population
  - Buildings
- Vulnerability
  - Damage data
  - Fragility functions

## Social Impact
*(mitigation actions)*

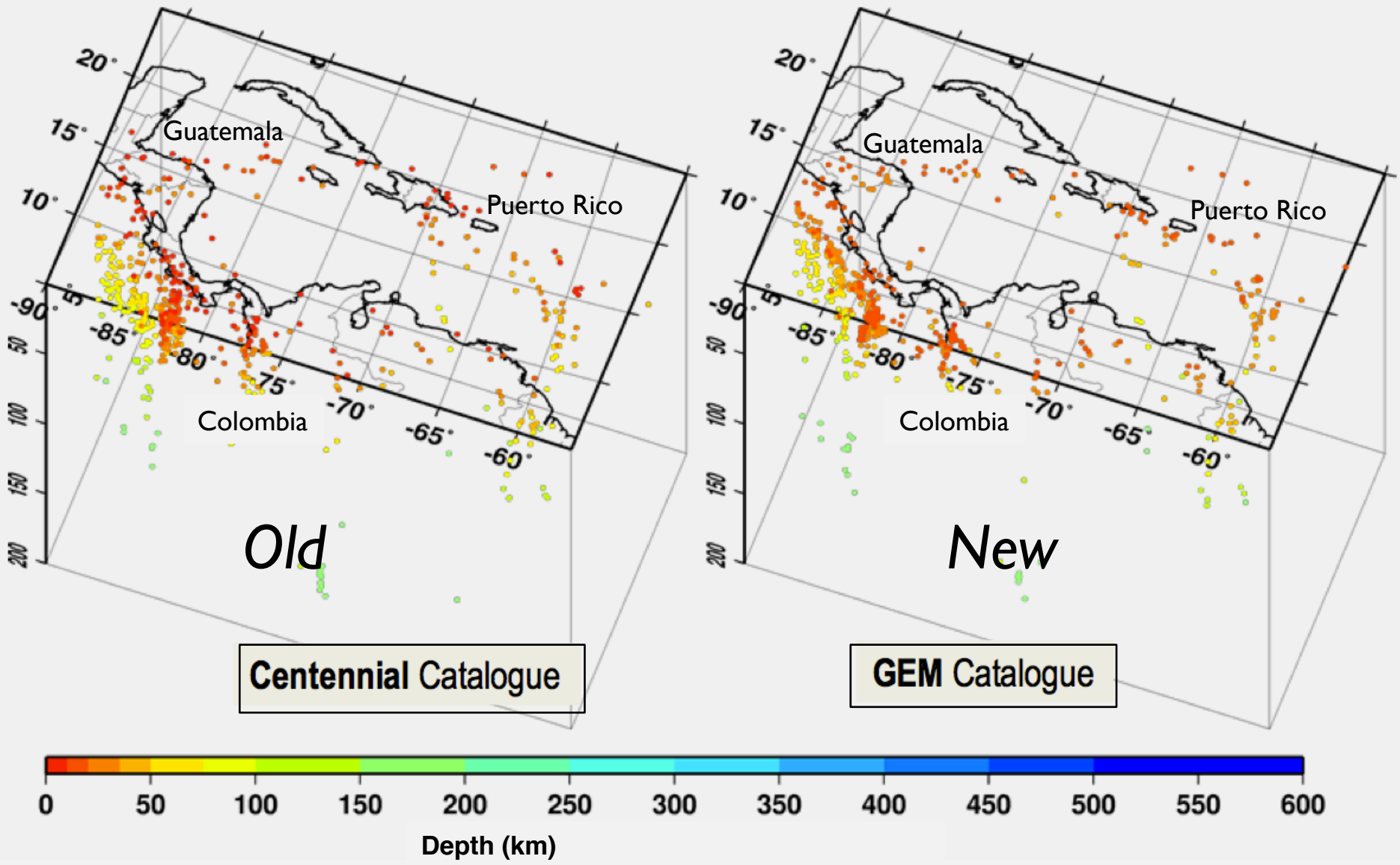
- Decision tools
- Loss amplifiers
- Risk transfer tools
- Retrofit cost-benefit tools
- Risk rankings and indices

GEM

# ISC-GEM Catalog: 20,000 earthquakes, 1900-2009



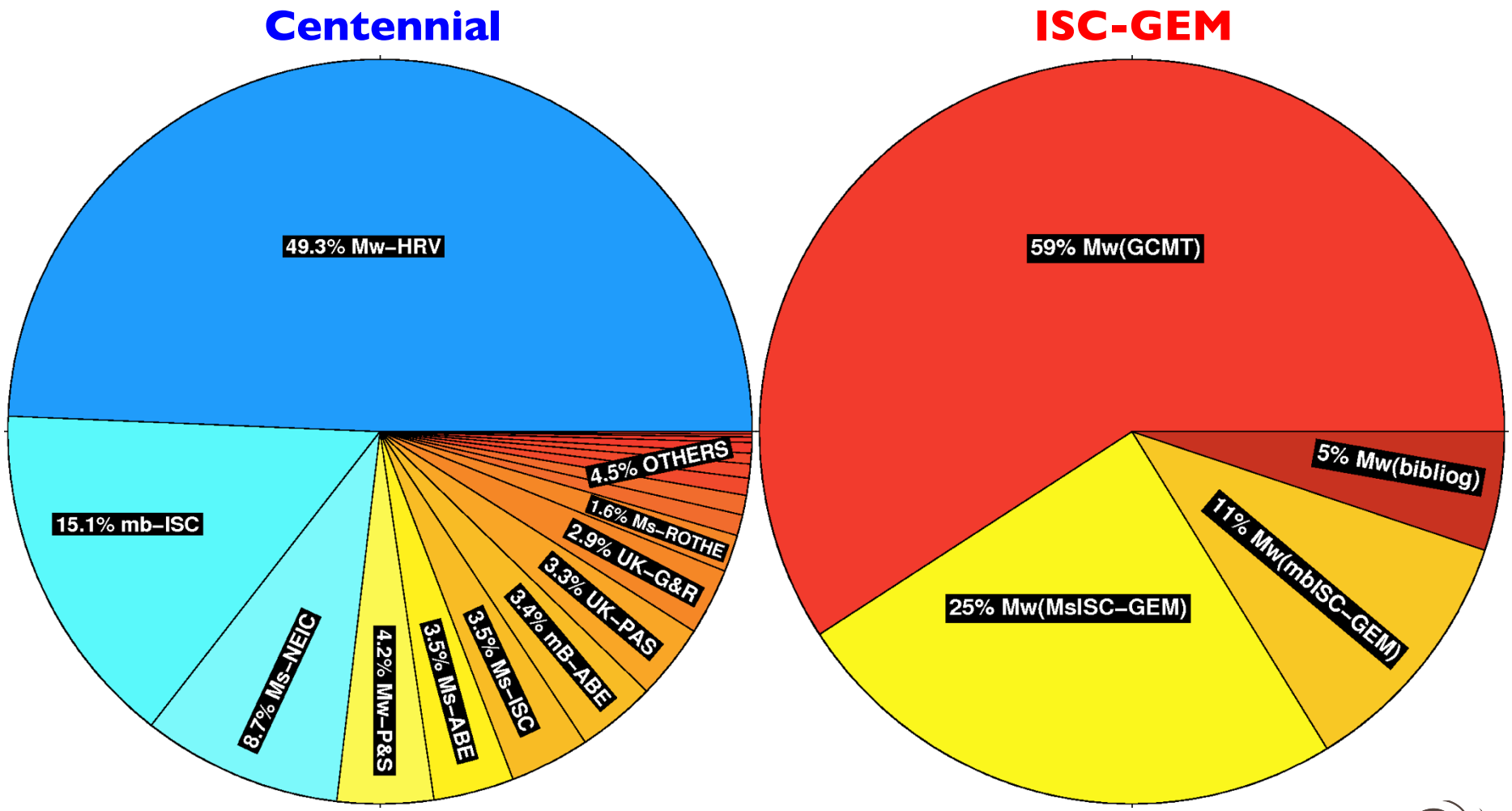
# ISC-GEM Catalog: New magnitudes, locations, and depths for all quakes




Storchak, Di Giacomo, Bondár, Engdahl, Villaseñor, Lee, Harris and Bormann (submitted)

# Uniform magnitudes

ISC-GEM uses a unified $M_W$ magnitude scale, originating from just four sources



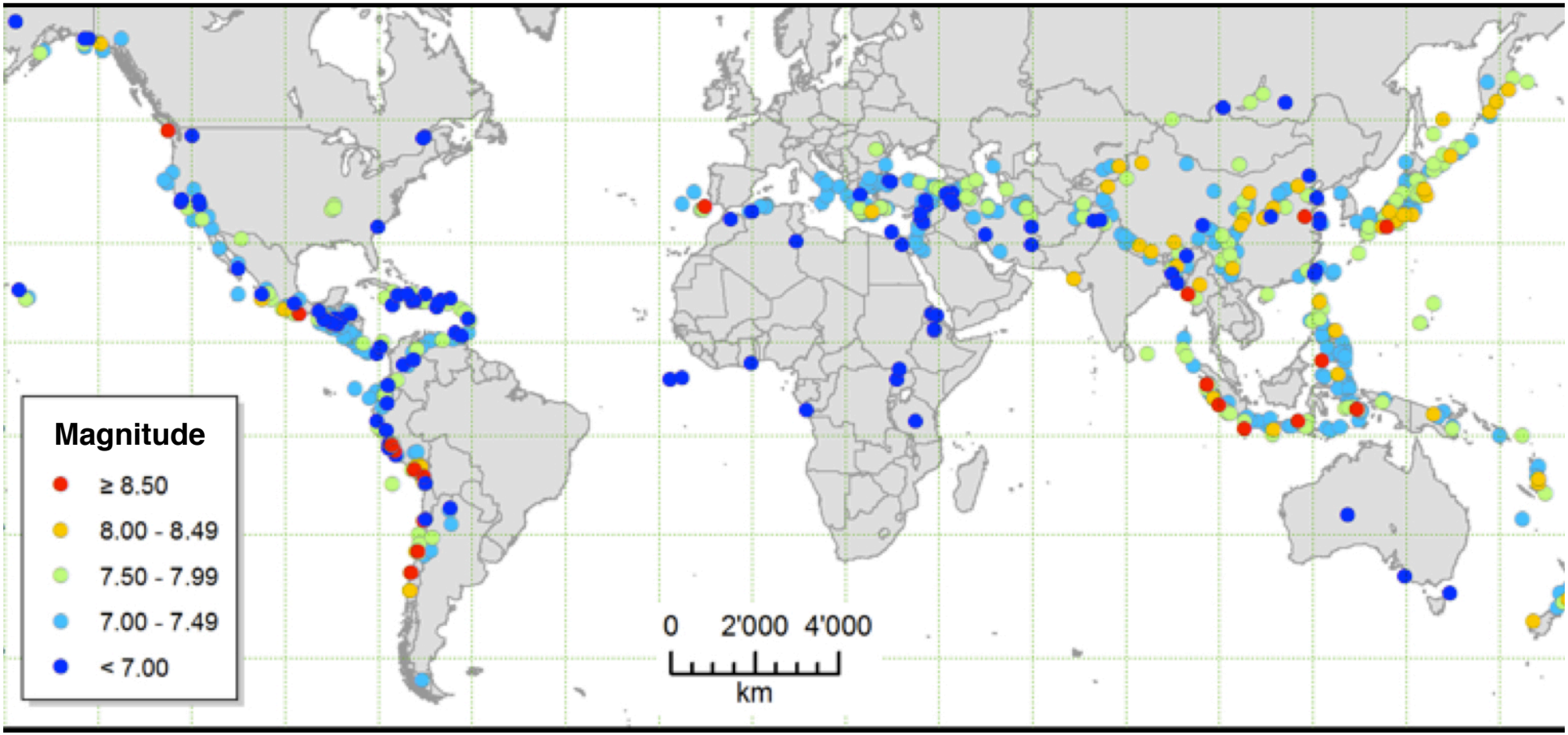

Ms, mb, mB, Mw, UK, others

Storchak et al (submitted)

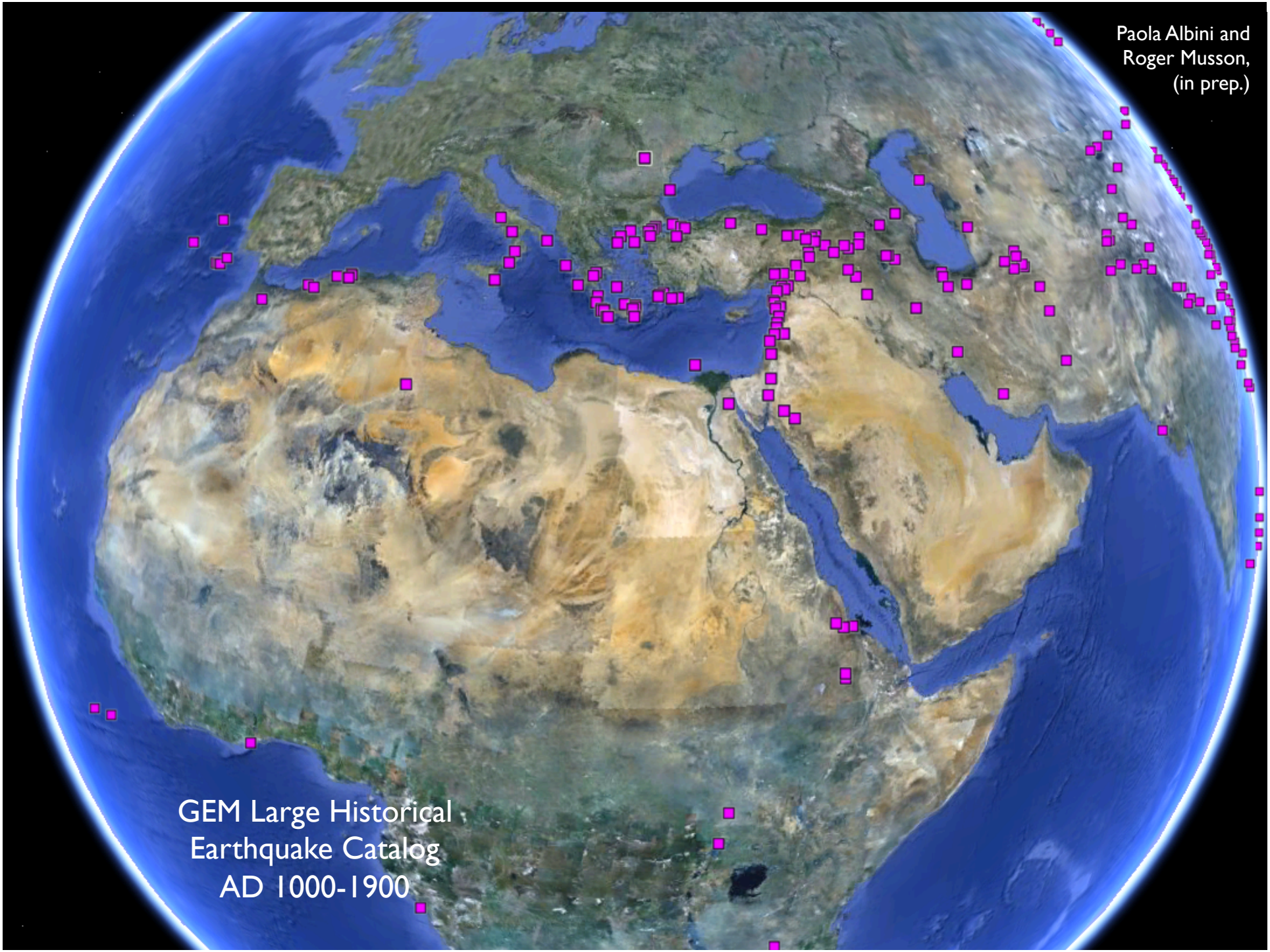
GEM

# Earthquake potential from millennial, century, and decade record

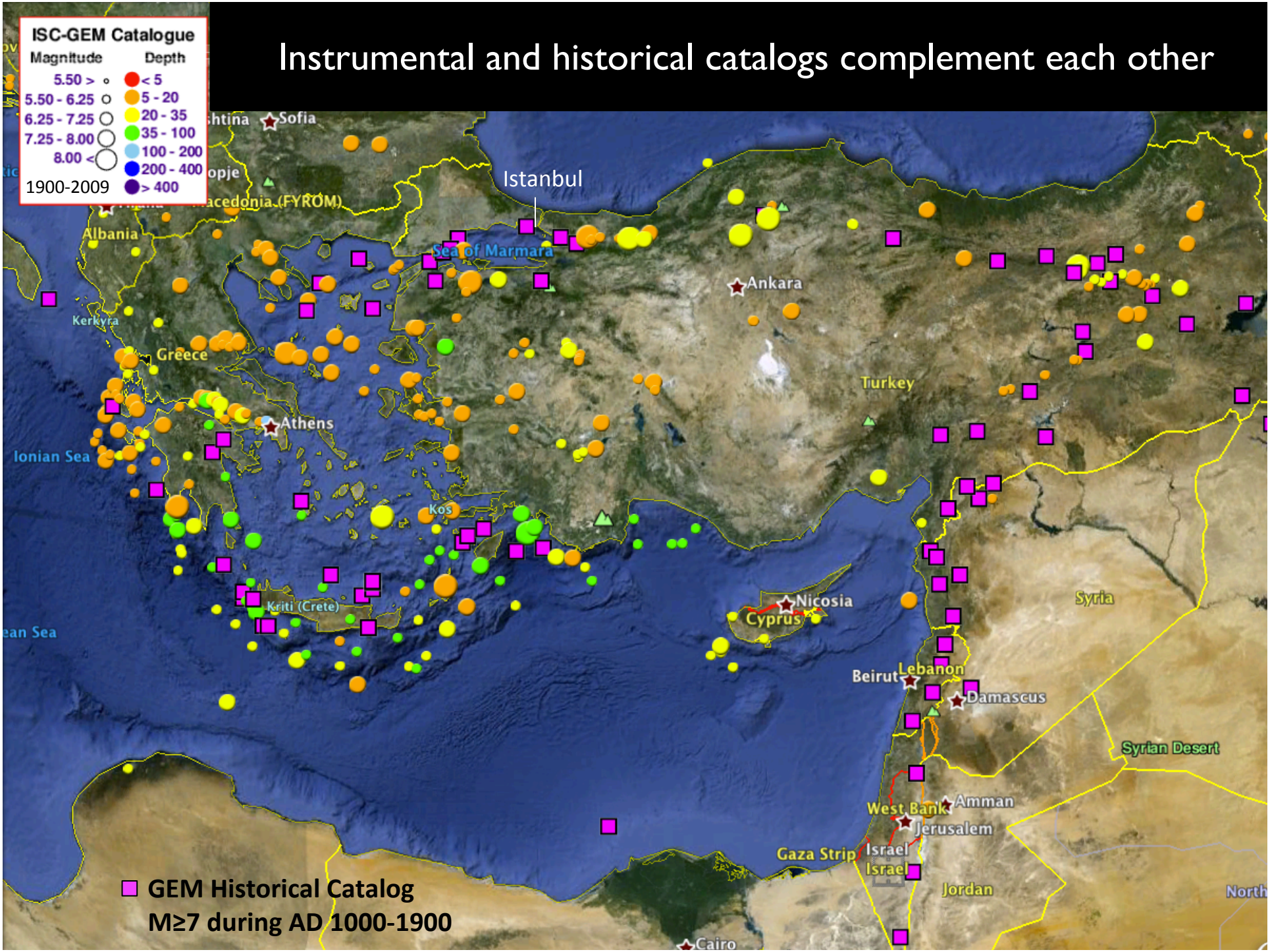
## GEM Large Historical Earthquake Catalog: 832 M≥7 quakes during AD 1000-1900



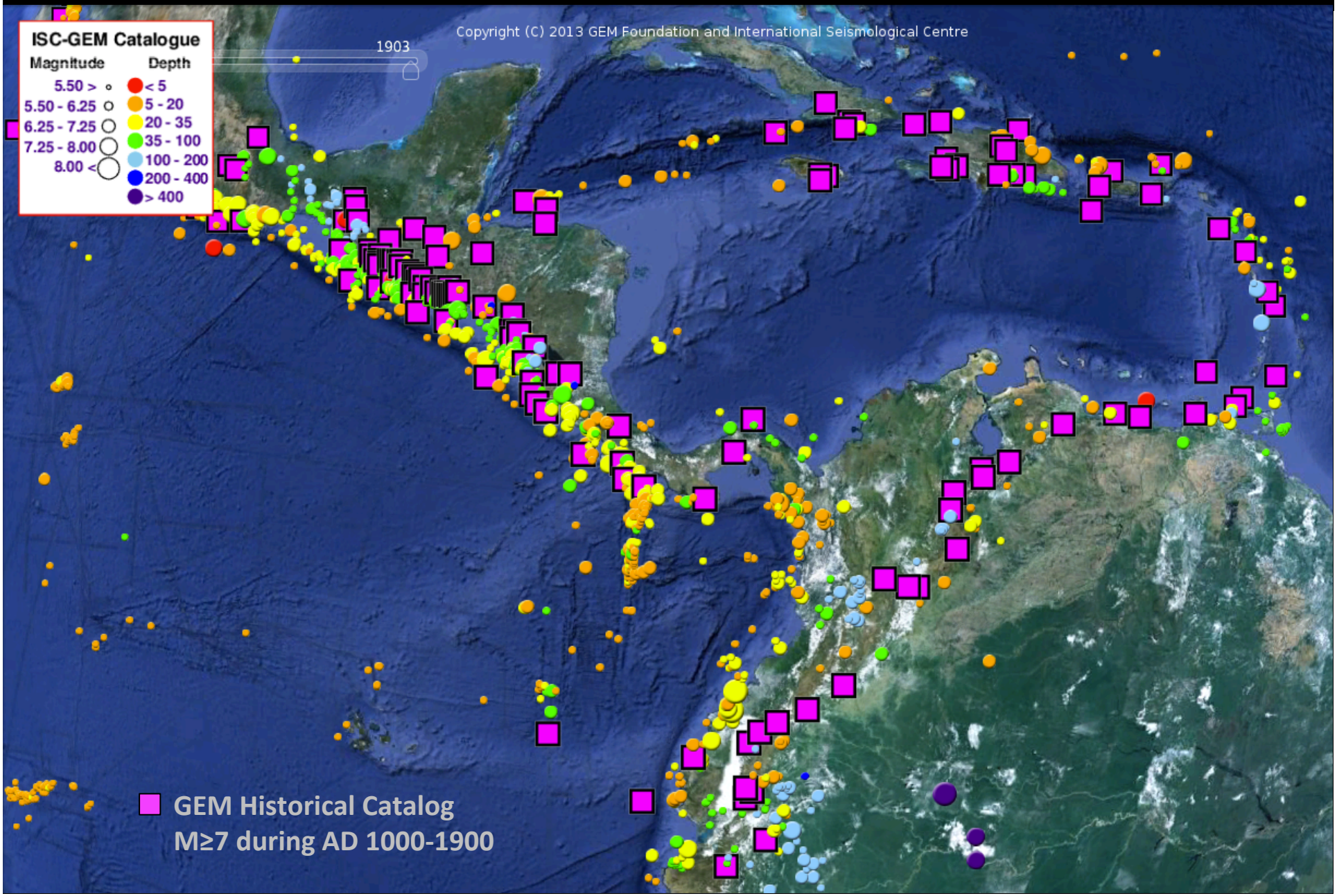

Paola Albini (INGV Milan) and Roger Musson (British Geological Survey), Principal Investigators


Paola Albini and
Roger Musson,
(in prep.)
GEM Large Historical
Earthquake Catalog
AD 1000-1900

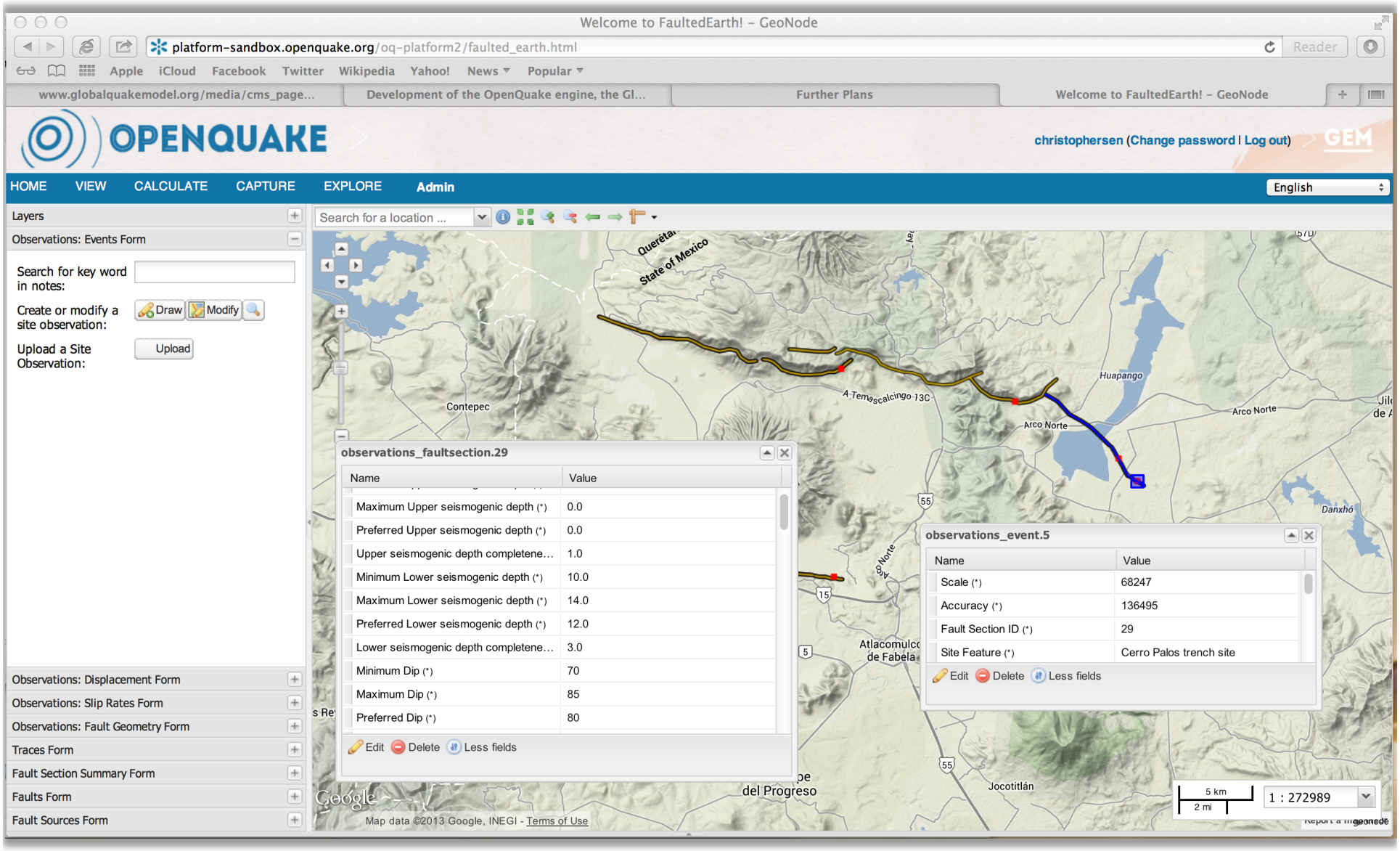
# Instrumental and historical catalogs complement each other



# Instrumental and historical catalogs complement each other



# GEM Faulted Earth: A new tool for geologists to upload faults data

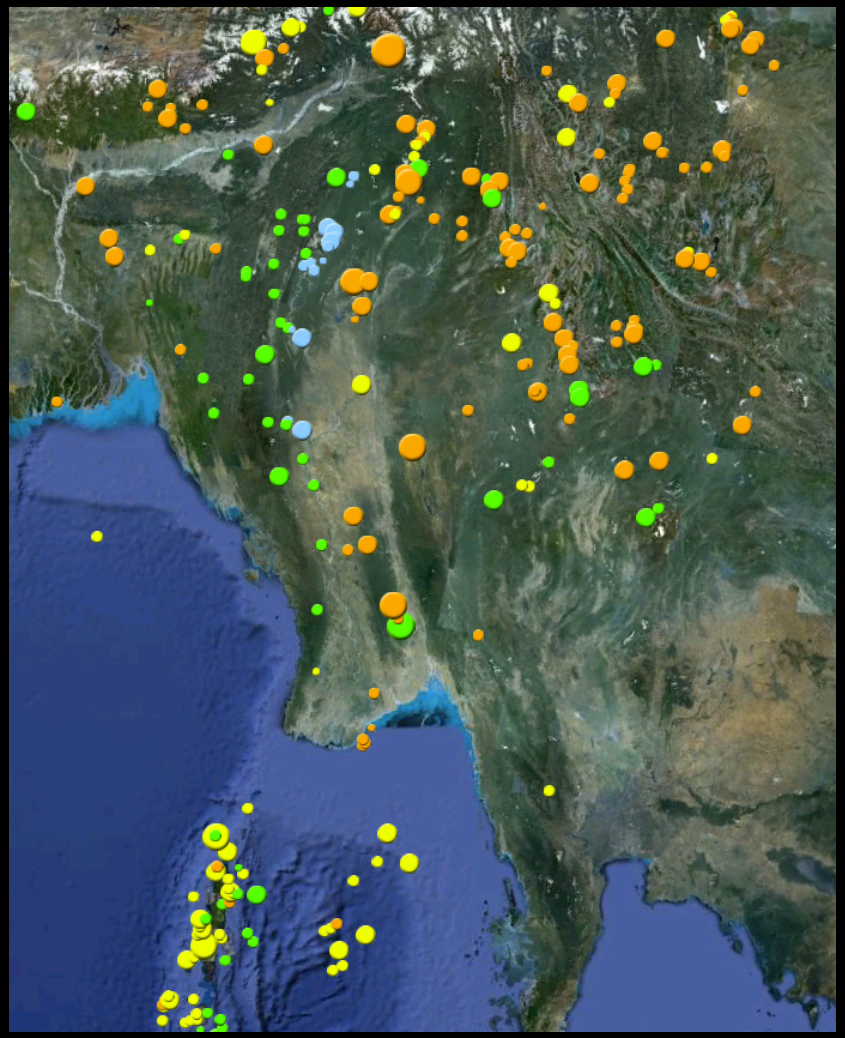



K. Berryman, A. Chistophersen, N. Litchfield, and GEM IT staff

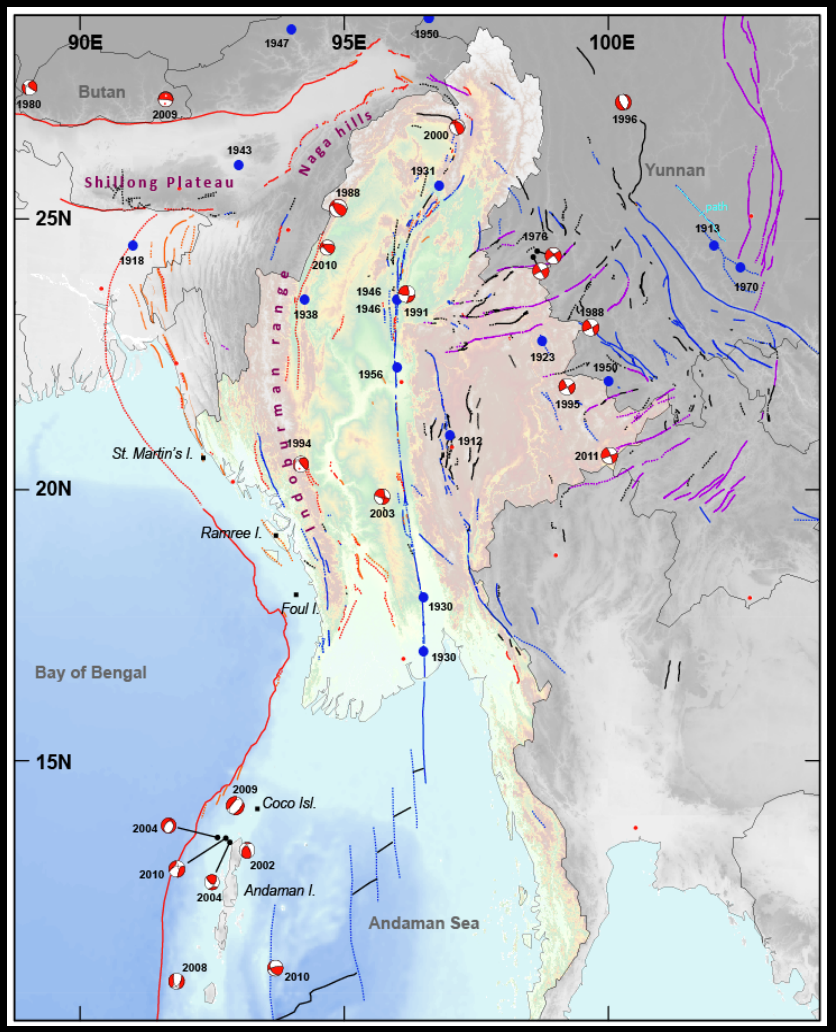
GEM

# GEM Faulted Earth

Newly discovered
active faults in Myanmar

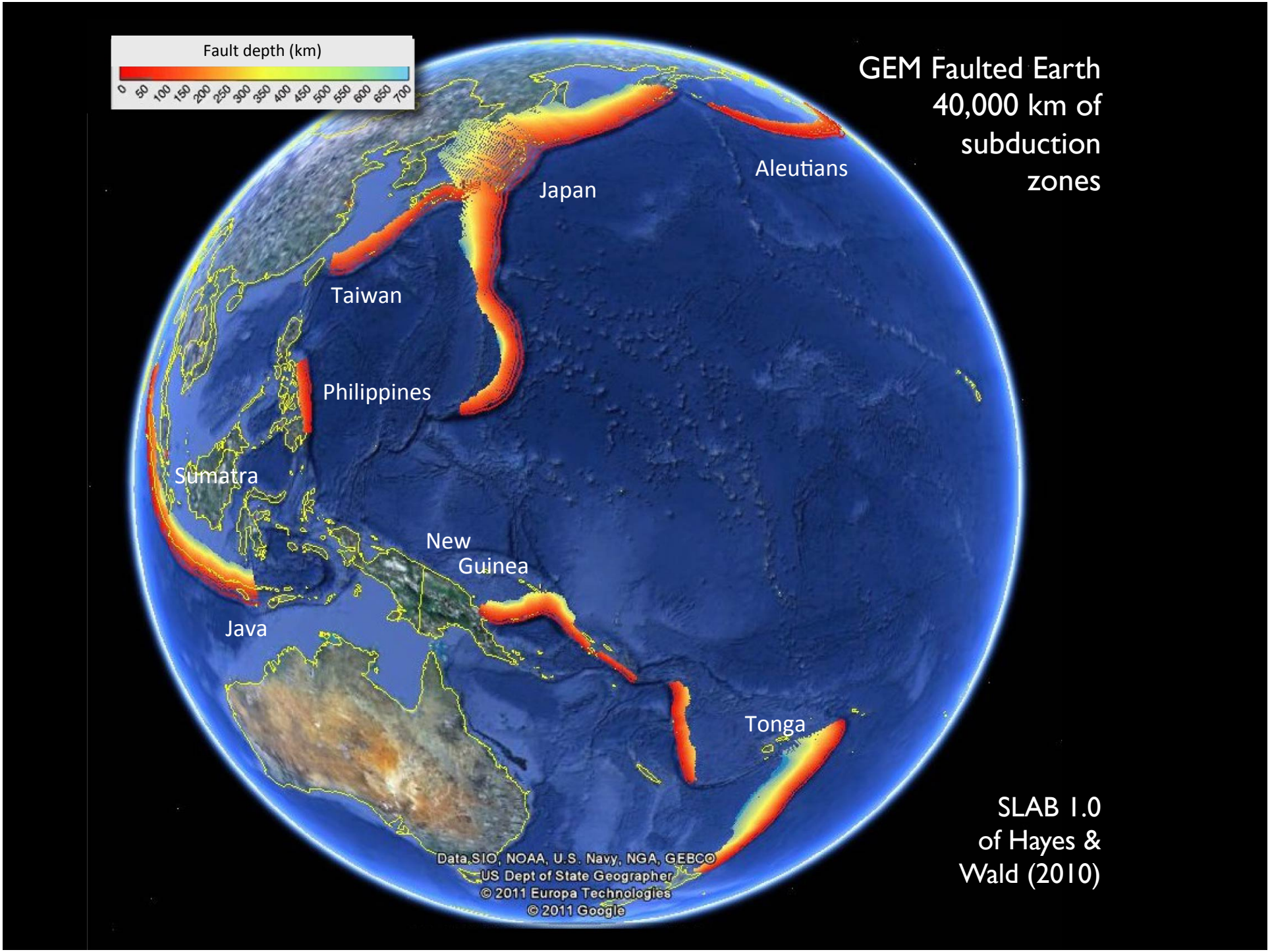


ISC-GEM Seismic Catalog

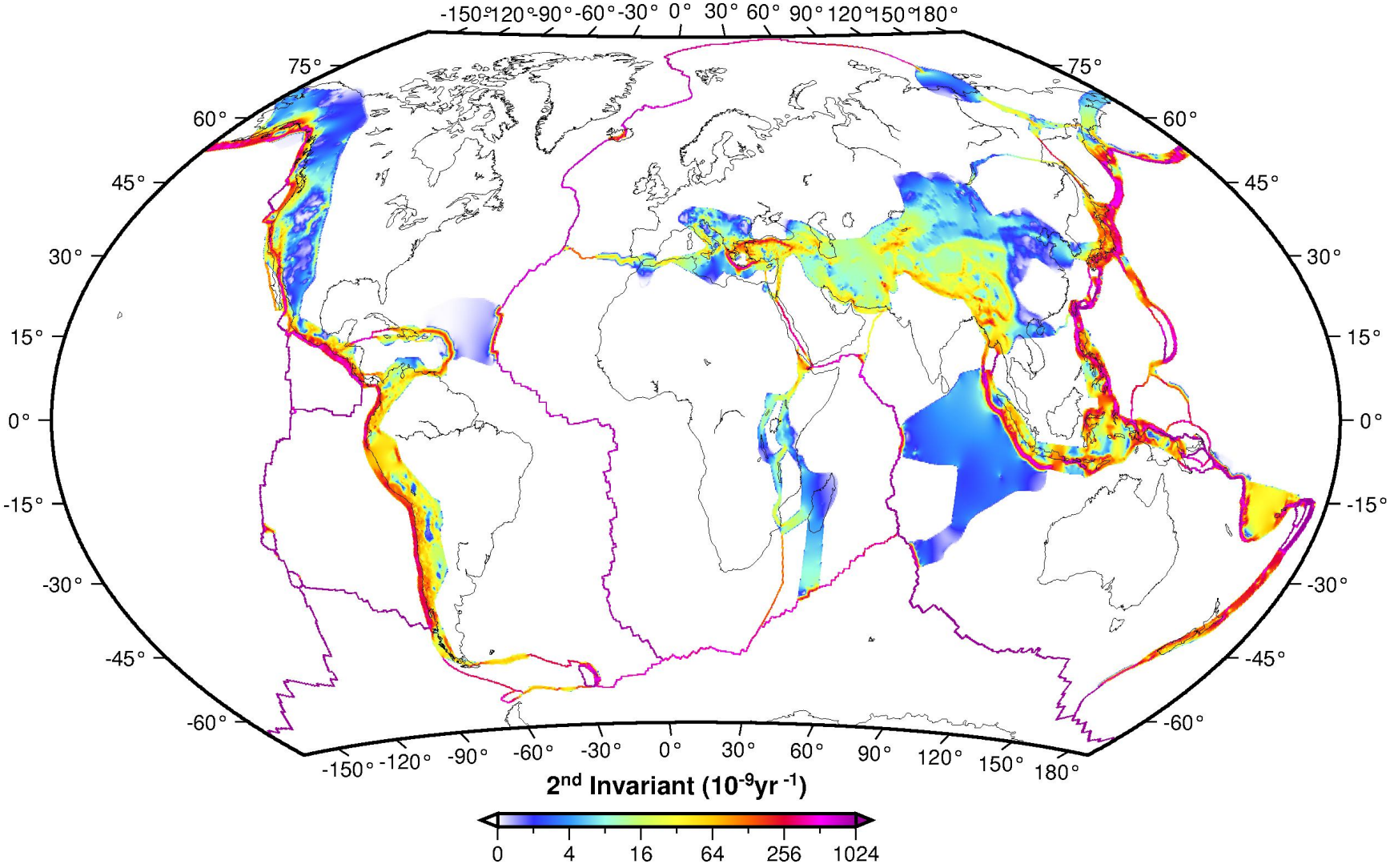



Sieh et al (in preparation)

GEM


Fault depth (km)
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
GEM Faulted Earth
40,000 km of
subduction
zones
Aleutians
Japan
Taiwan
Philippines
Sumatra
New
Guinea
Java
Tonga
SLAB 1.0
of Hayes &
Wald (2010)
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
© 2011 Europa Technologies
© 2011 Google

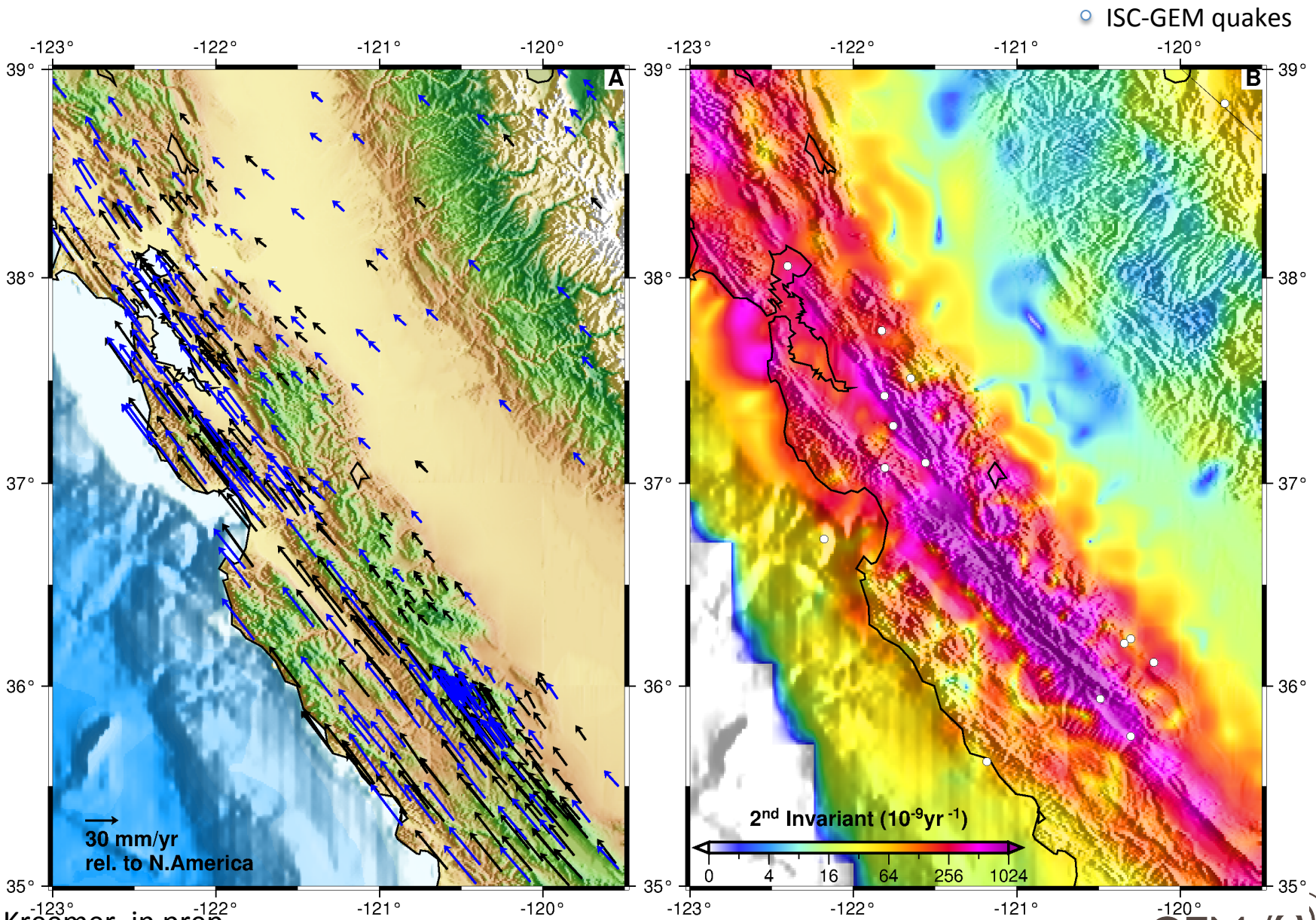
# GEM Global Strain Rate model




4,000 velocities in 2004 model, 20,000 in GEM's (Kreemer, in prep.)

GEM

# GEM Global Strain Rate model

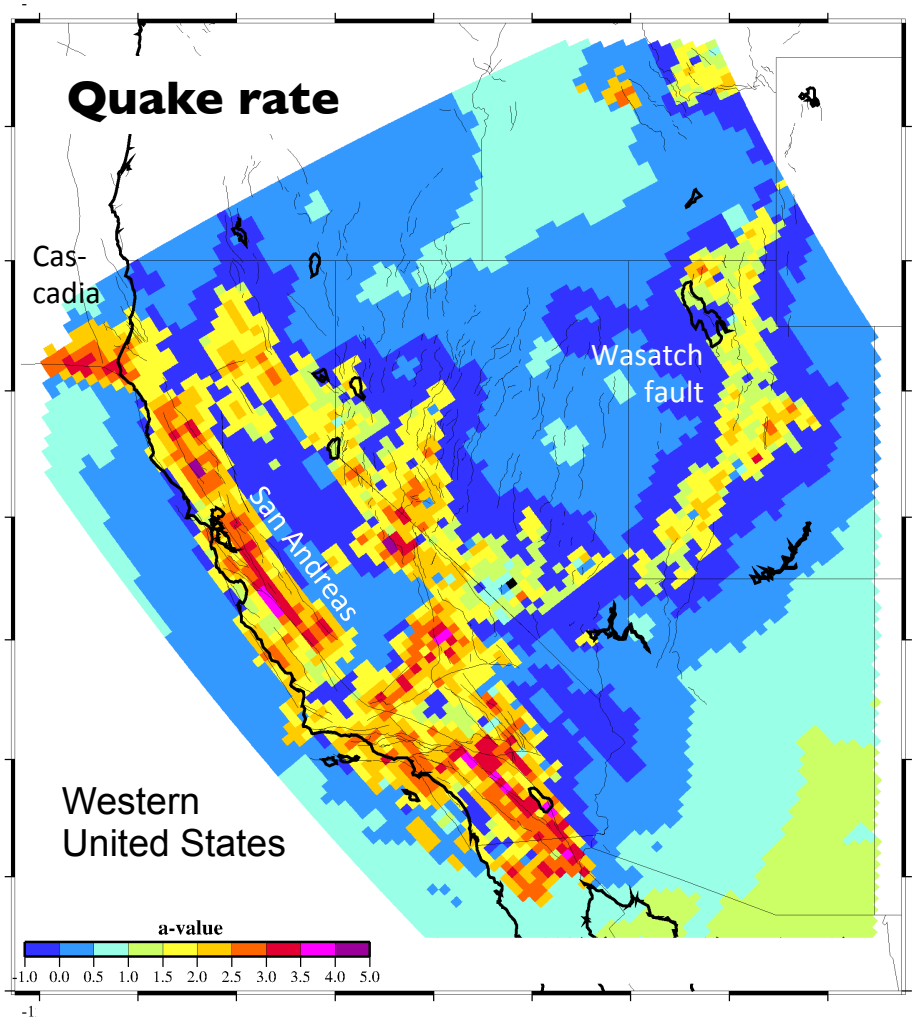



Kreemer, in prep.

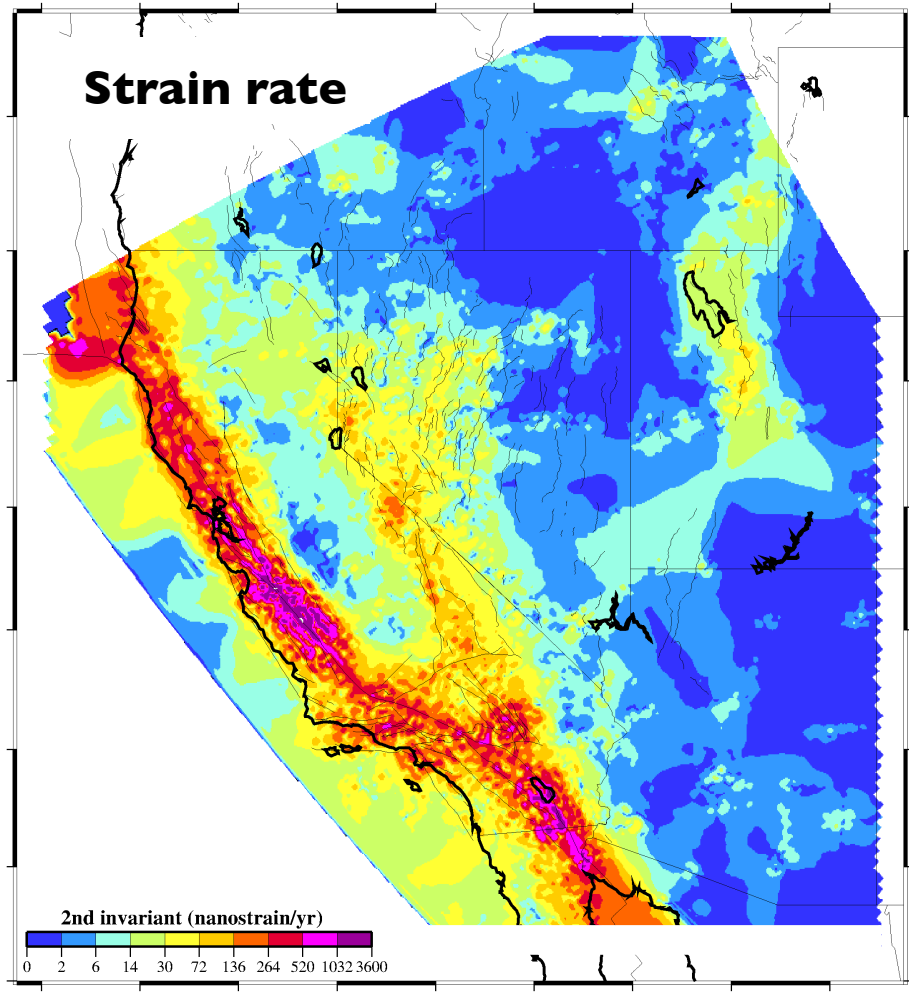
GEM

# Combining strain-rates from earthquakes and geodesy

*If all accumulating strain were released seismically, the quake rate should be proportional to strain rate*



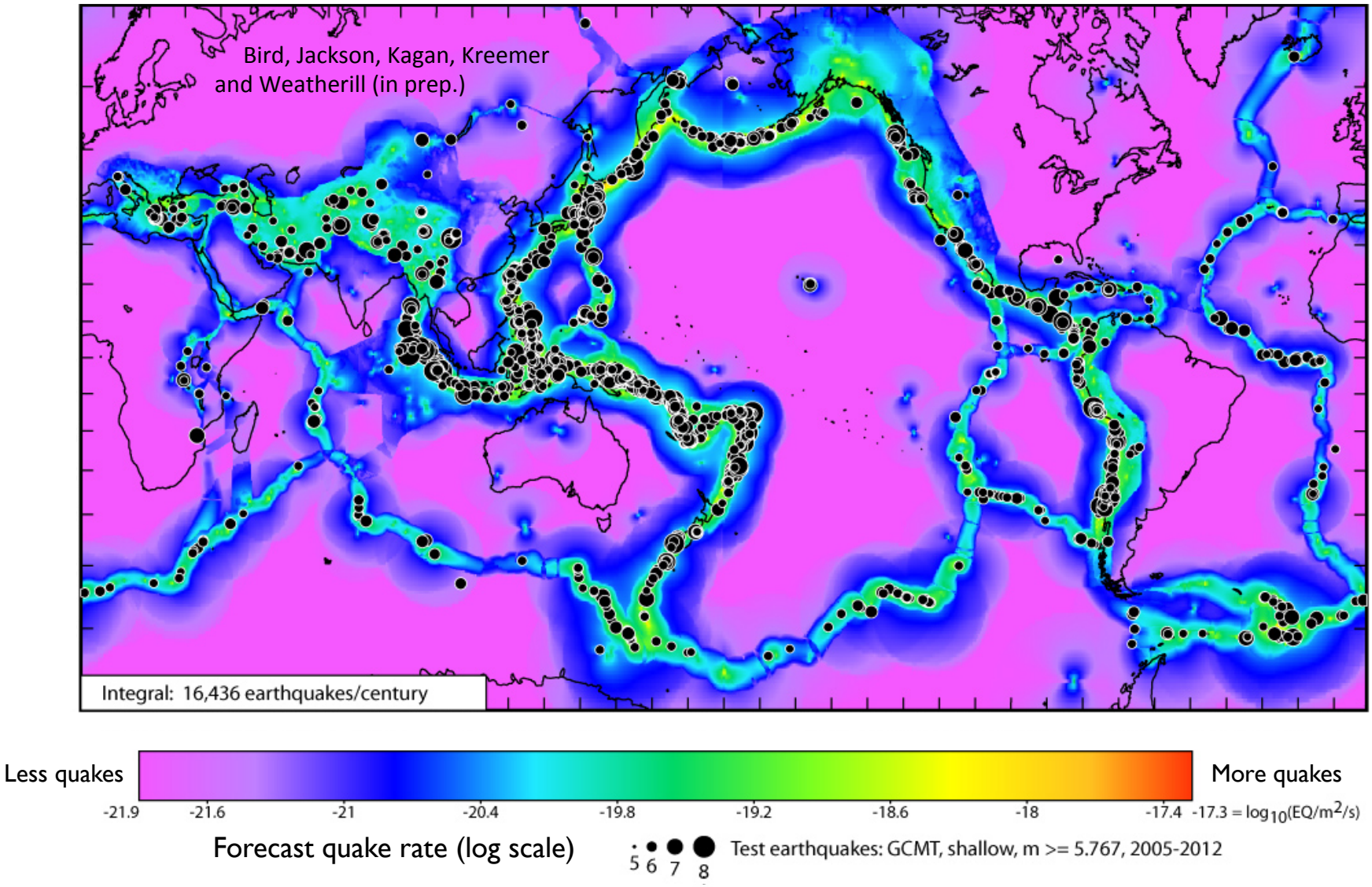

Gutenberg-Richter a-value from declustered ANSS catalog (Arnaud Mignan, ETH Zurich)

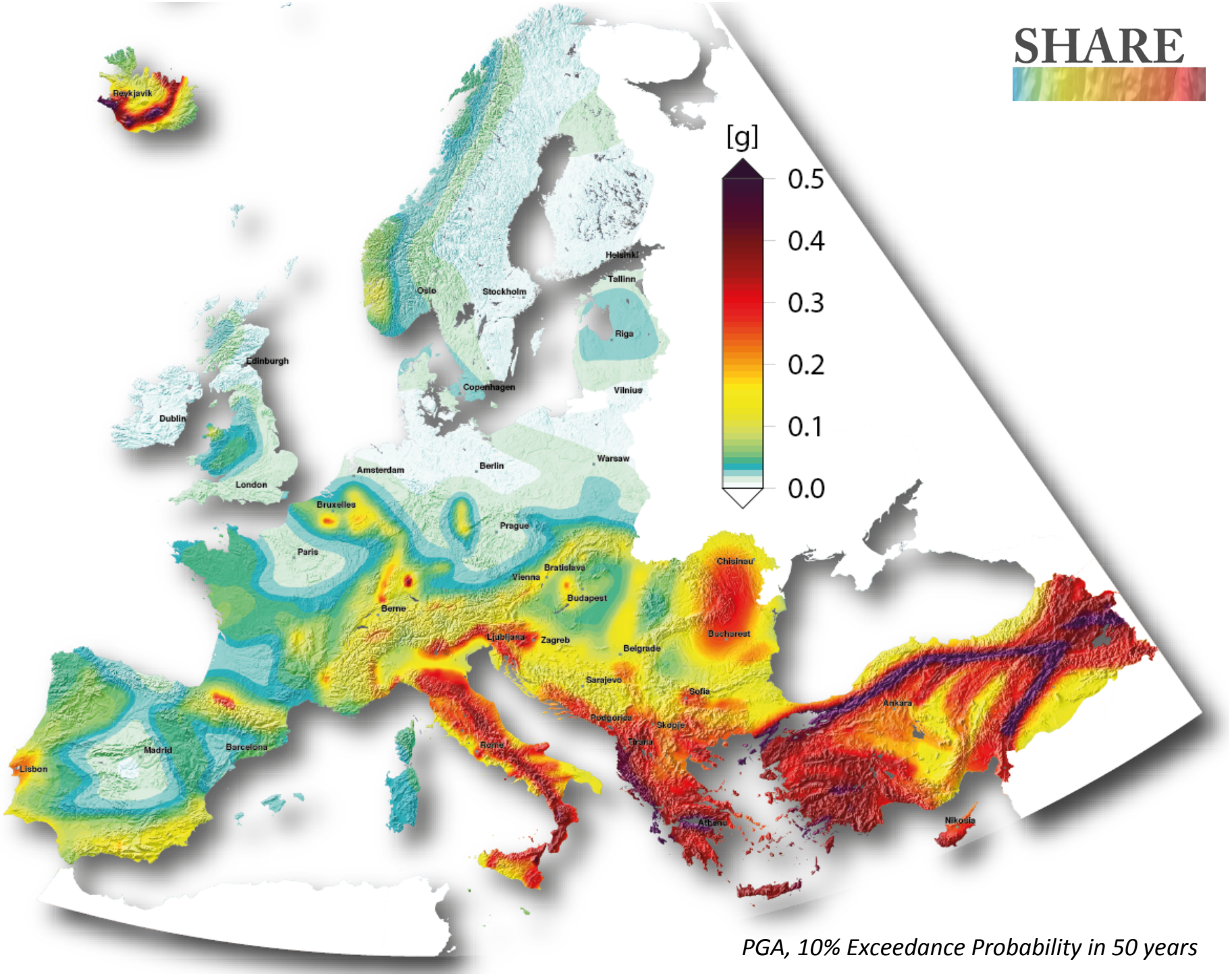



2000-2011 GPS velocities used by Kreemer et al for the GEM Strain Rate Model

# GEM Earthquake Activity Rate (GEAR) retrospective forecast for post-2005 M≥5.75 quakes

*Best forecast is from 37.5% GEM Strain Rate Model and 62.5% pre-2005 seismic catalog*

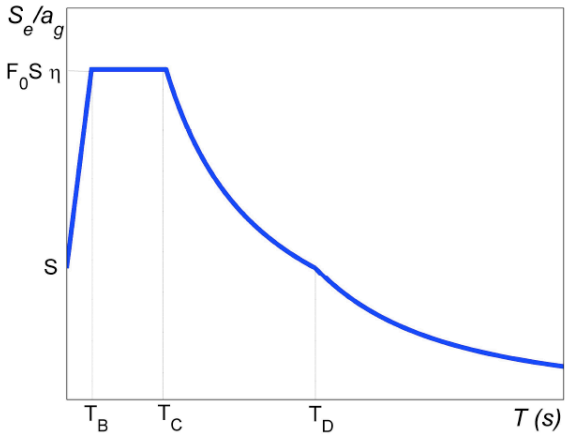




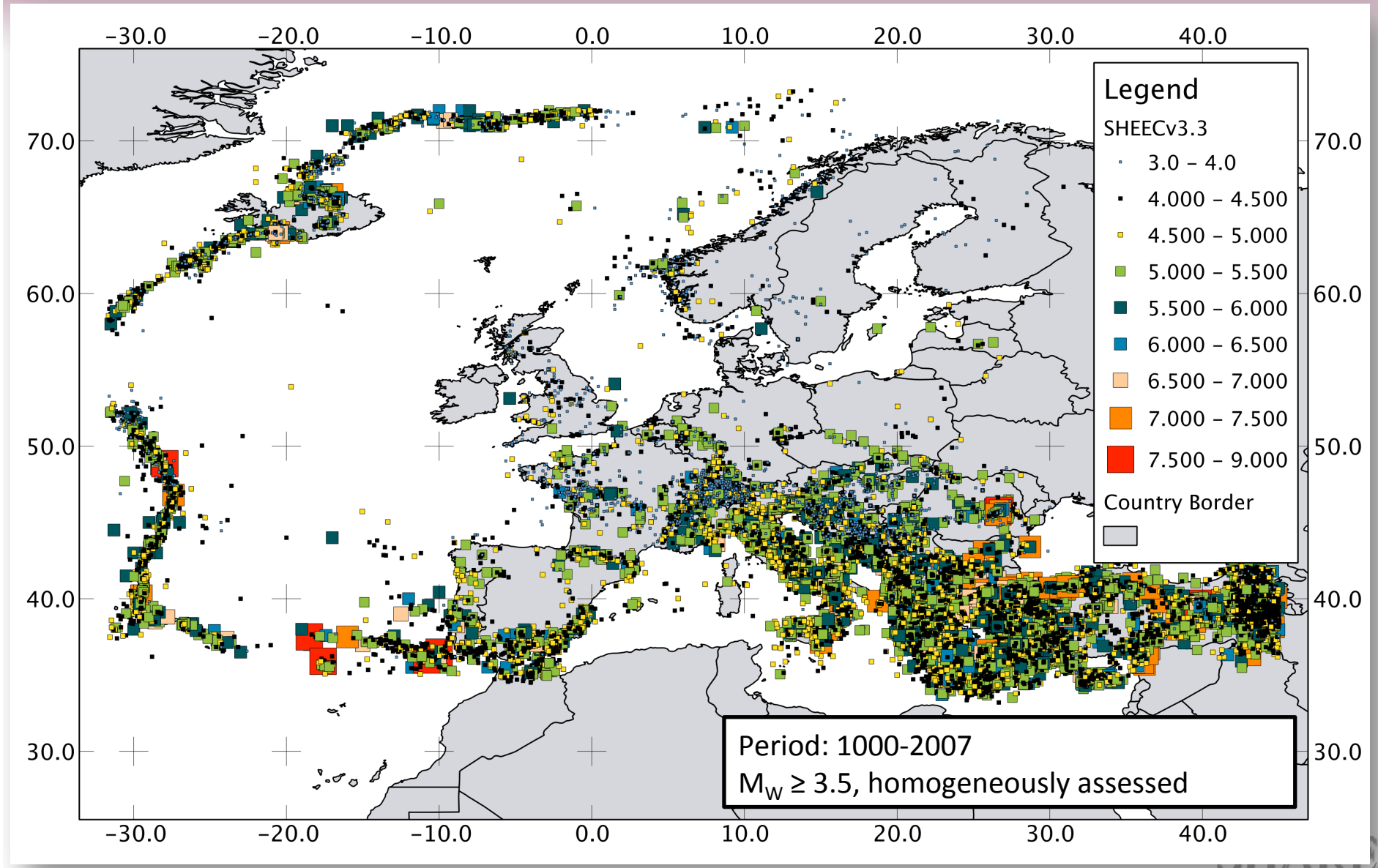

*PGA, 10% Exceedance Probability in 50 years*

# Engineering Requirements

- **Hazard maps for a range of return periods** for median PGA, multiple median Spectral Ordinates (SA), PGV and PGD
  - Return periods: 25-5'000 years
- **Zonation Map for Europe** based on PGA (EN 1998-1 3.2.1 (1)P, EN 1998-1 3.2.1 2), corresponding to the no collapse requirement (EN 1998-1 3.2.1 3)
- **PSHA disaggregation** in terms of PGA and spectral ordinates
- **Uniform hazard spectra**
- **Zonation map for Europe** considering both PGA and spectral shape
- Hazard maps, for aforementioned return periods, of median $F_0$, $T_B$, $T_C$, $T_D$ at a reference bedrock level
- Full account of **epistemic uncertainties**

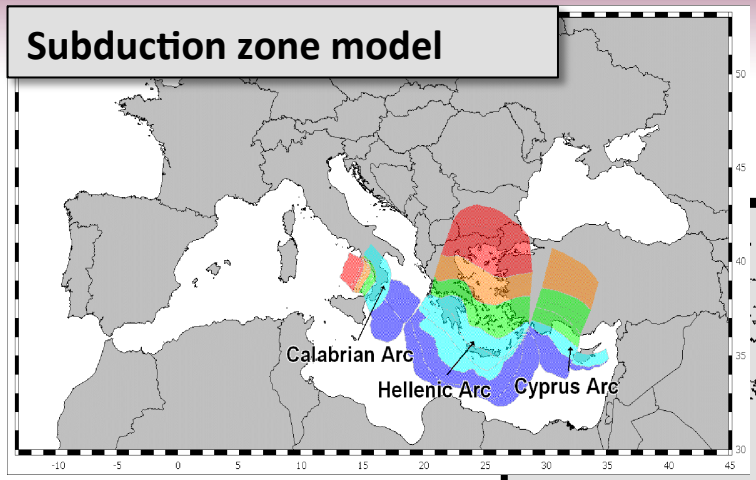


# SHare European Earthquake Catalog (SHEECv3.3)

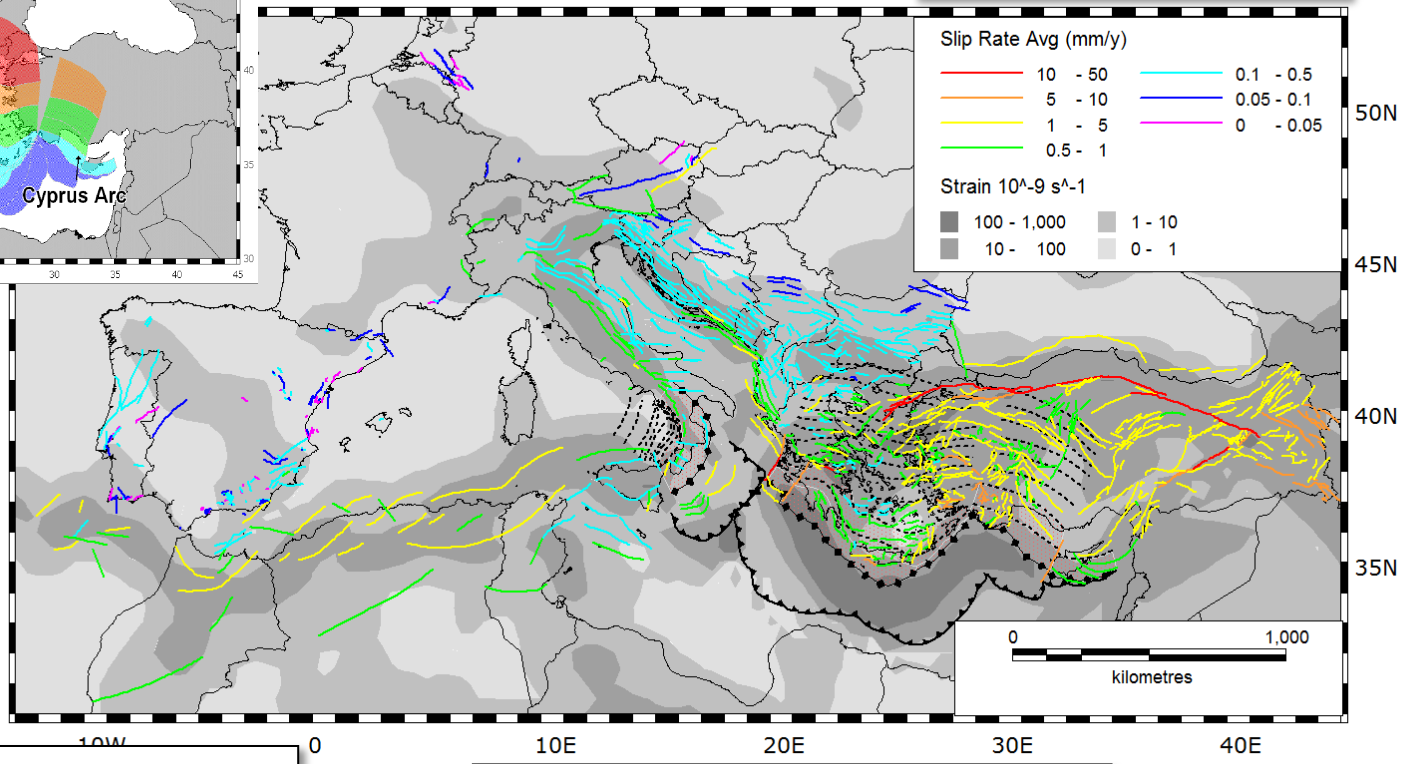


# Euro-Mediterranean Fault Database & Subduction Model

**Subduction zone model**




**Crustal fault model**




**Strain Rate Model in Background**
**Barba & Carafa (2012)**

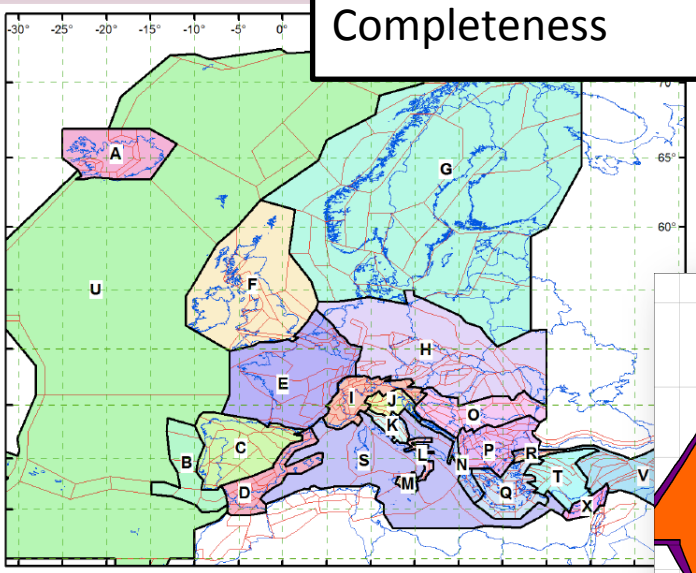
Project start (2009)
- 98 data records,
- ~8500 km of faults

*(Basili et al., 2008, Tectonophysics)*

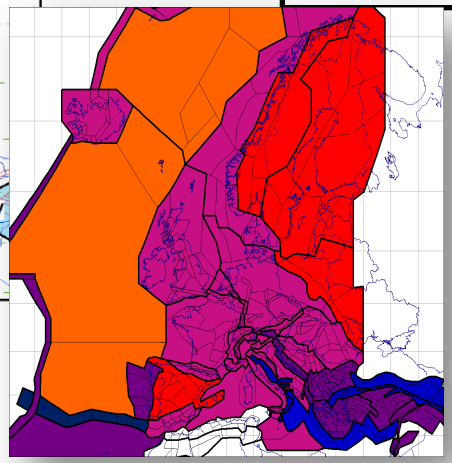
**Project end (2012):**
- **1128 data records**
- **~64000 km of faults**

# Regionalization

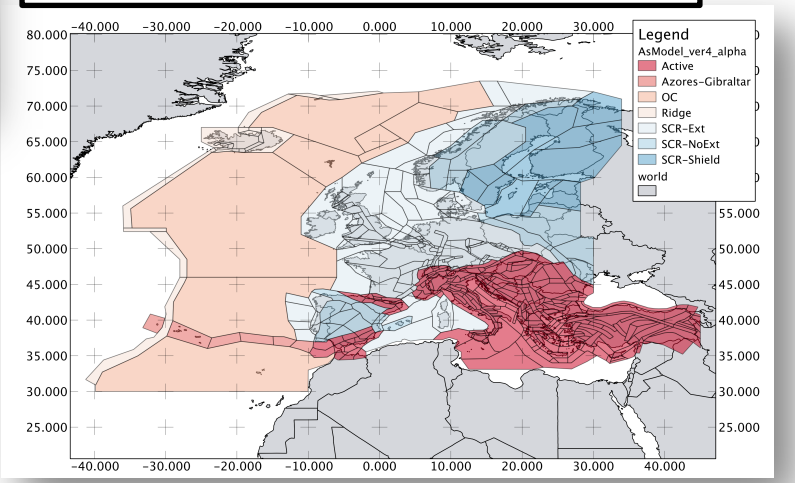
Completeness



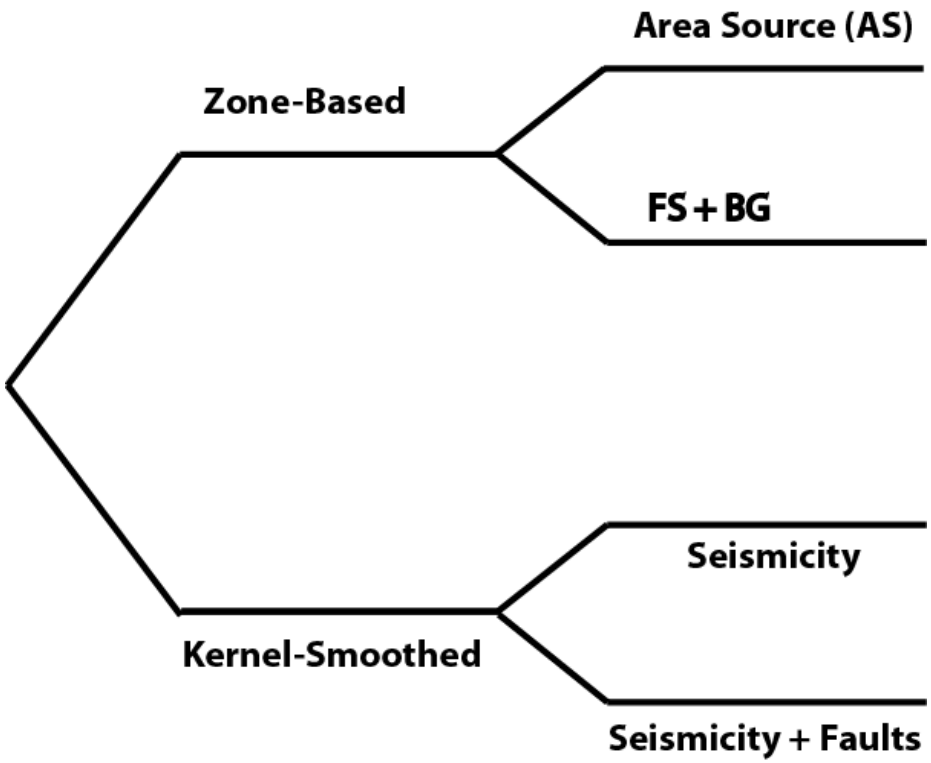

Mmax



Tectonic Regionalization



# SHARE Source Models



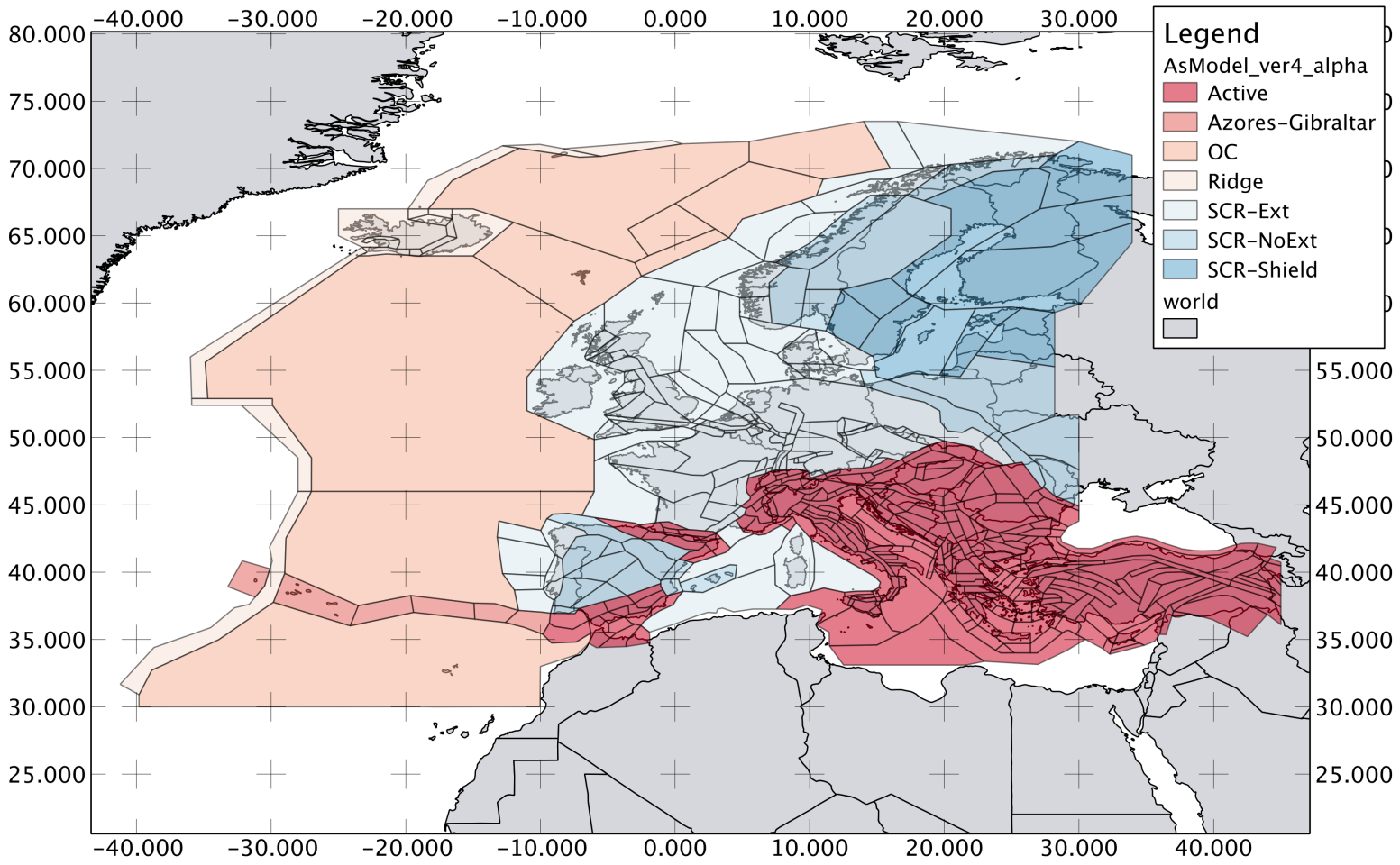

**Traditional Area Source (AS) Model**

**Fault Source (FS) + BackGround (BG) Model**

**Smoothed Seismicity Model**
**(Woo, 1996; Grünthal et al., in prep)**

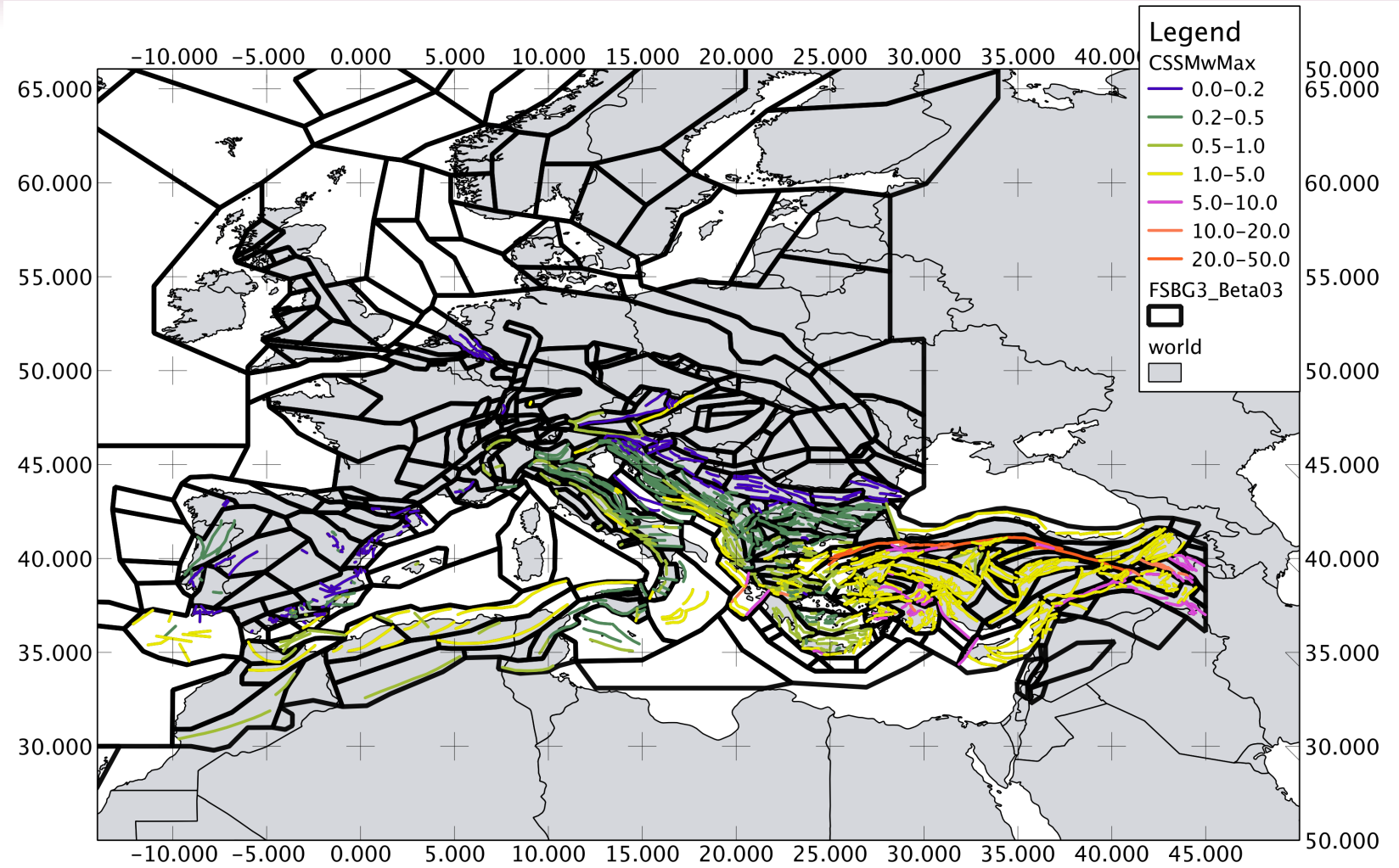
**Stochastic Earthquake Source Model**
**(Hiemer et al., 2013; Hiemer, Woessner et al. in prep.)**

# Area Source Model

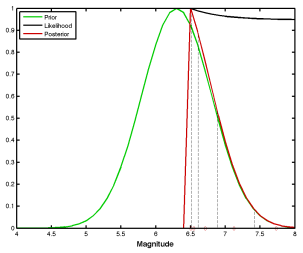



- Harmonization of former national and regional PSHAs
- Subduction zones modeled as fault structures (not in figure)

# Fault + Background model



# Strategy for $M_{max}$ in Different Tectonic Regimes



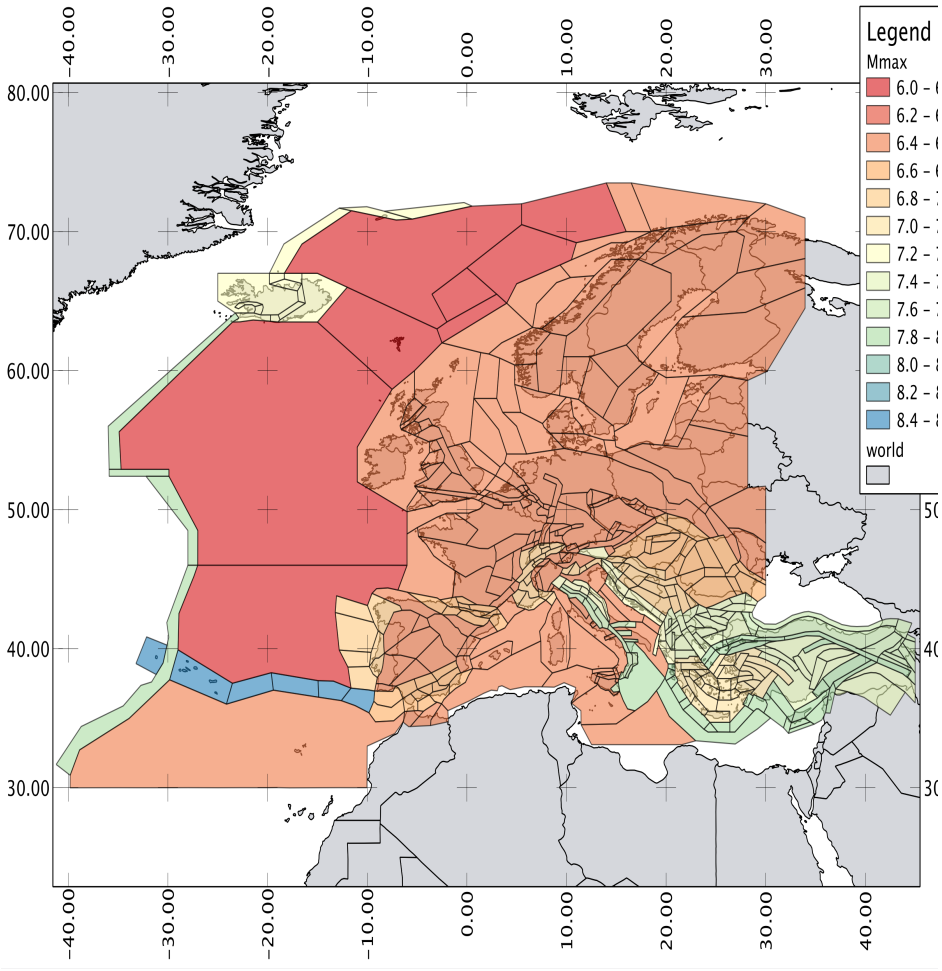




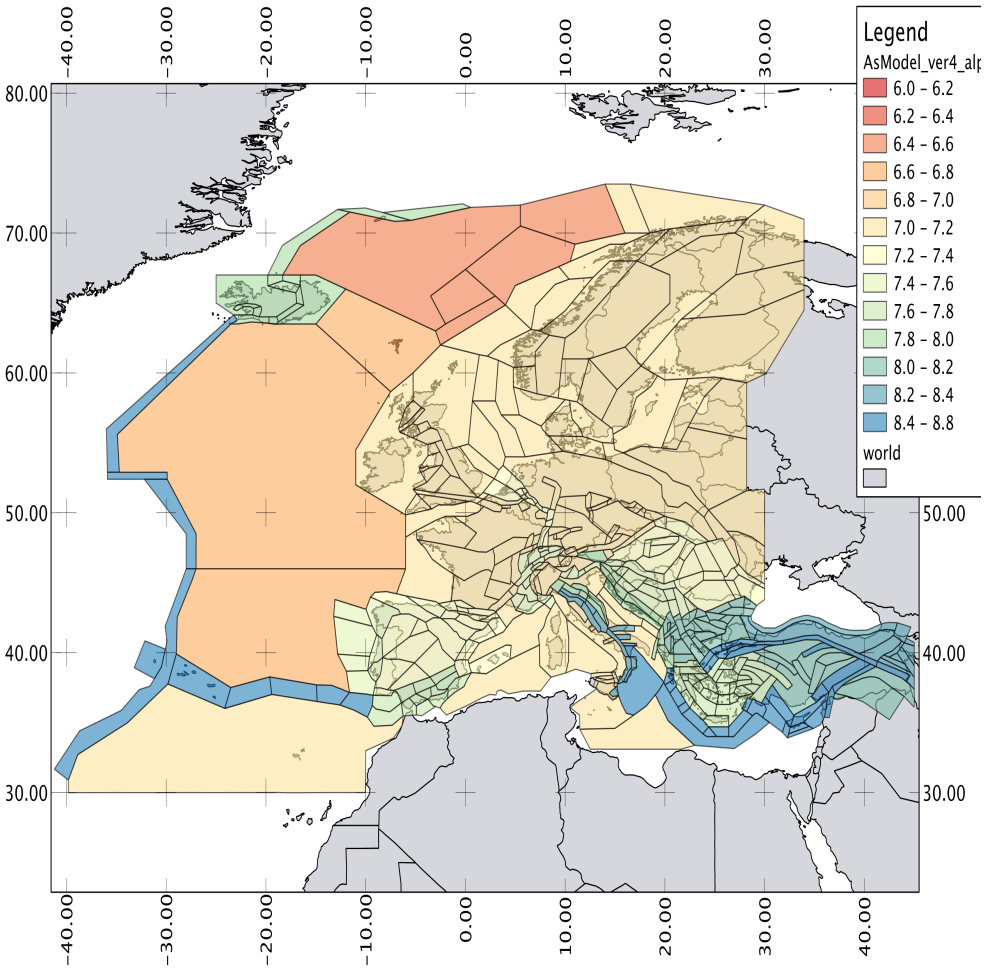
F. Meletti, V. D'Amico (INGV)

# $M_{max}$ distribution

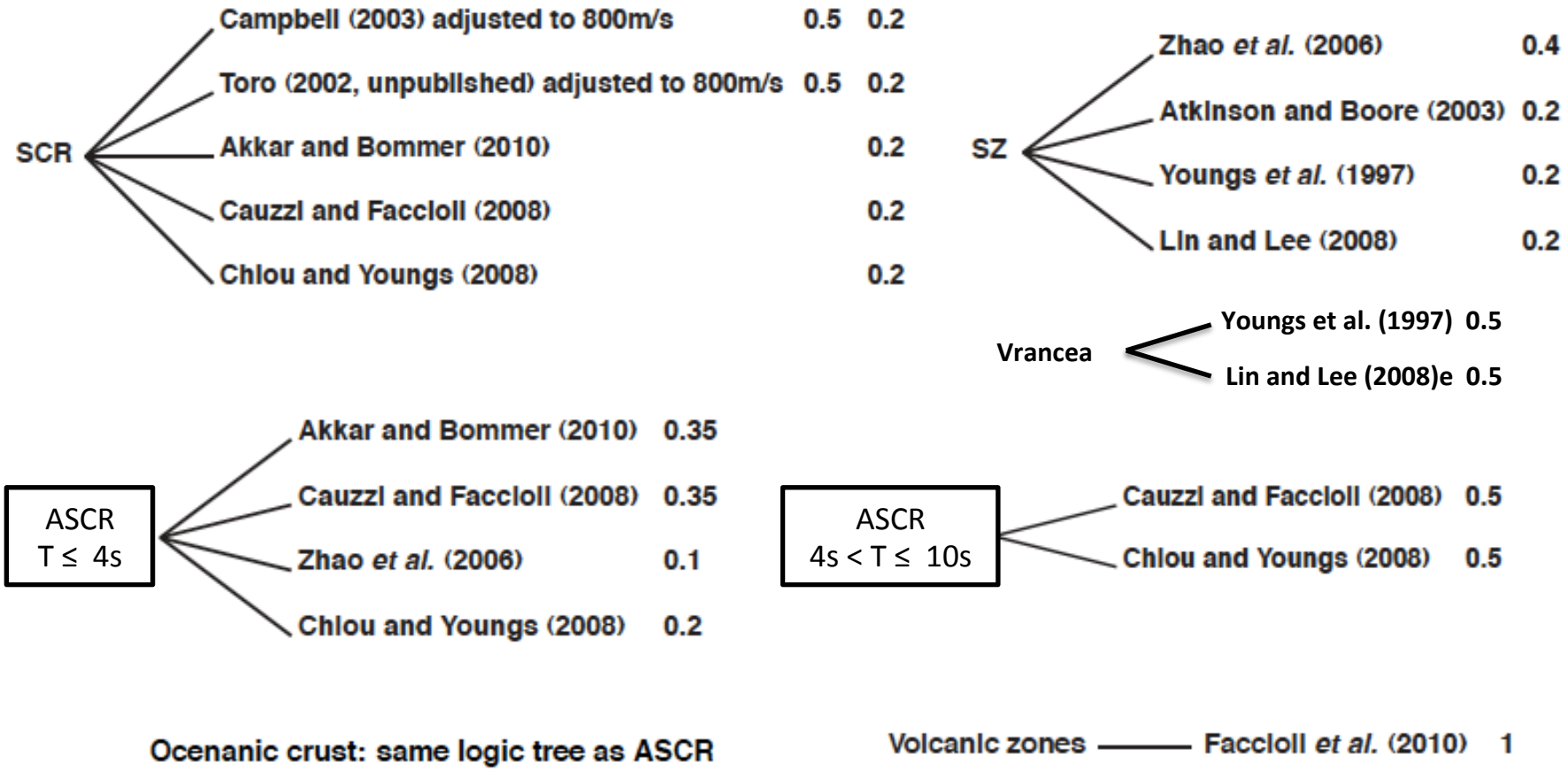
Lowest $M_{max}$




Highest $M_{max}$



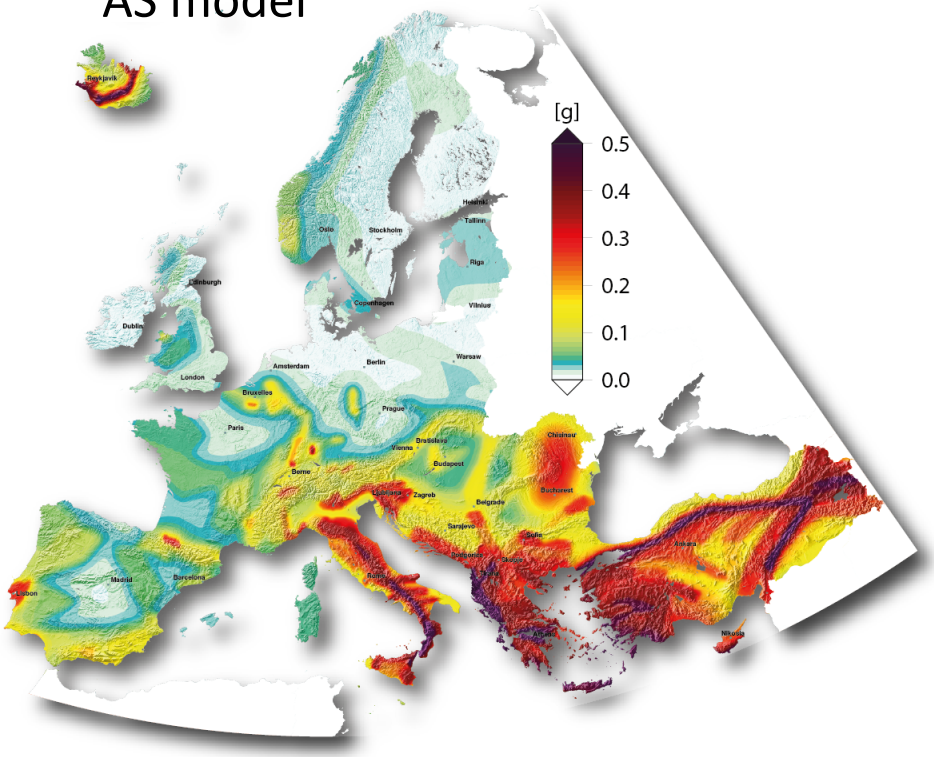
# GMPE Logic Tree



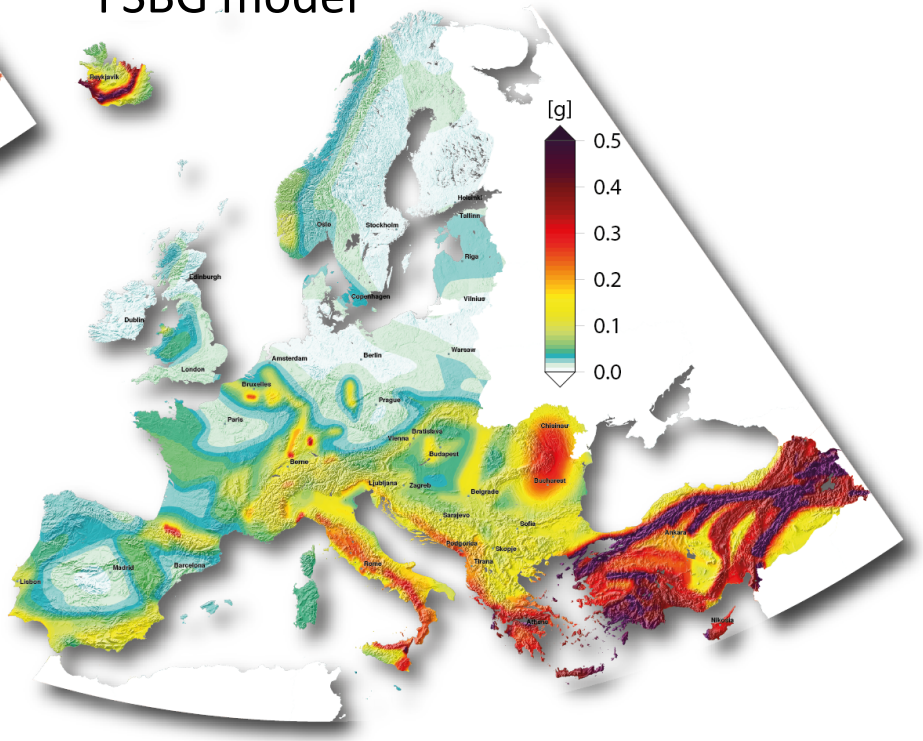

Delavaud et al., 2012, J. Seis.

# SHARE hazard: Area Sources vs Fault Sources

AS model



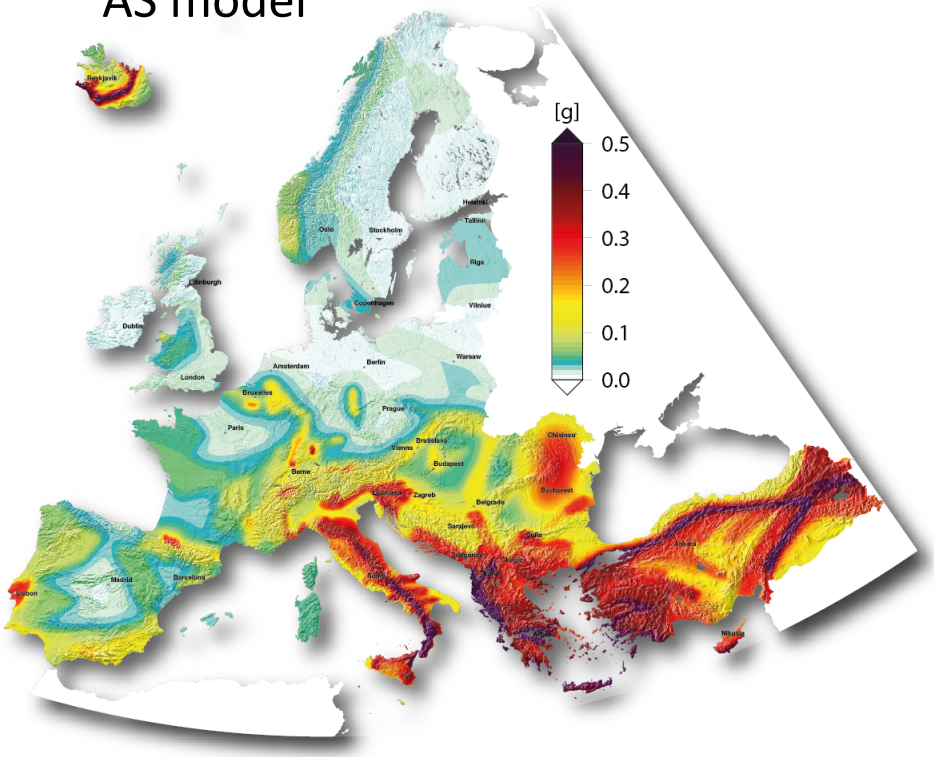

FSBG model



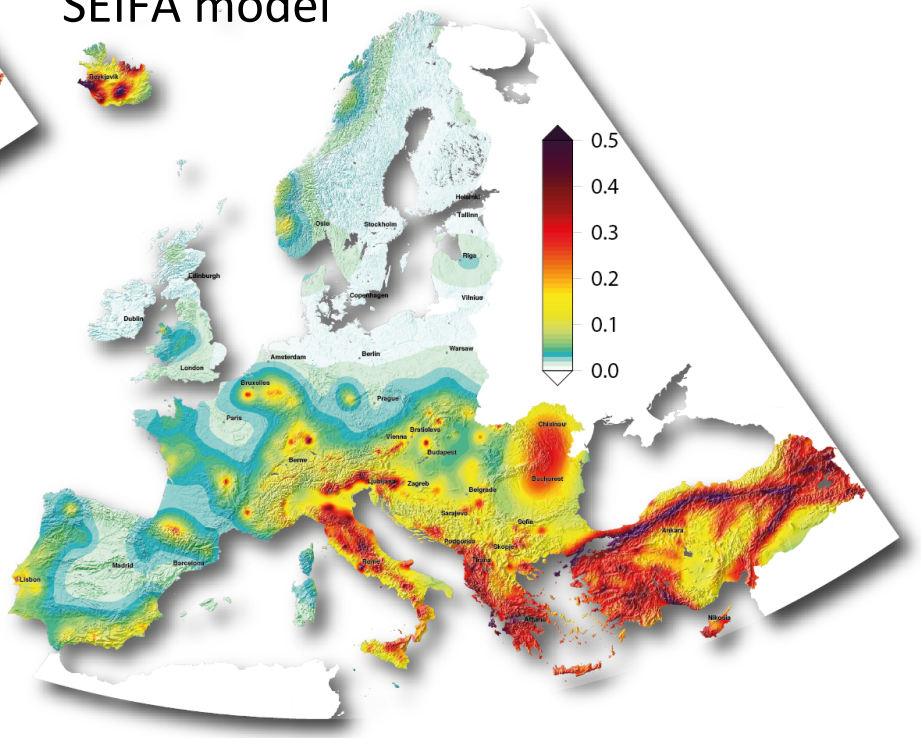

*PGA 475 yr*

# SHARE hazard: Area Source vs Smoothed Seismicity

AS model



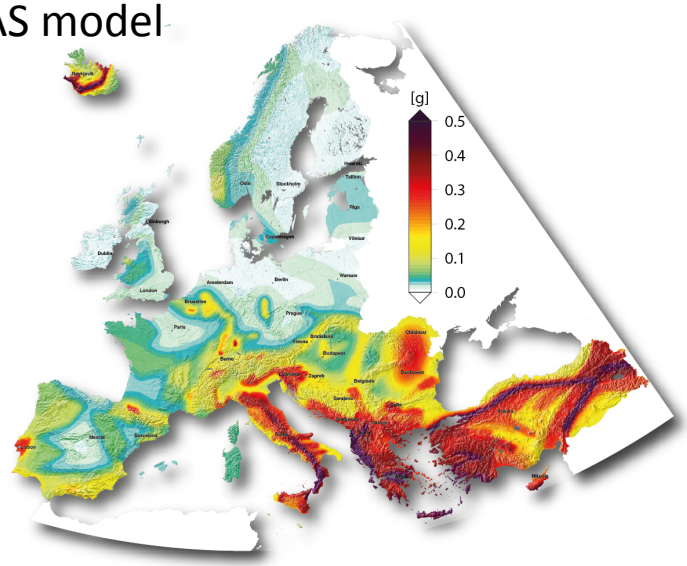

SEIFA model



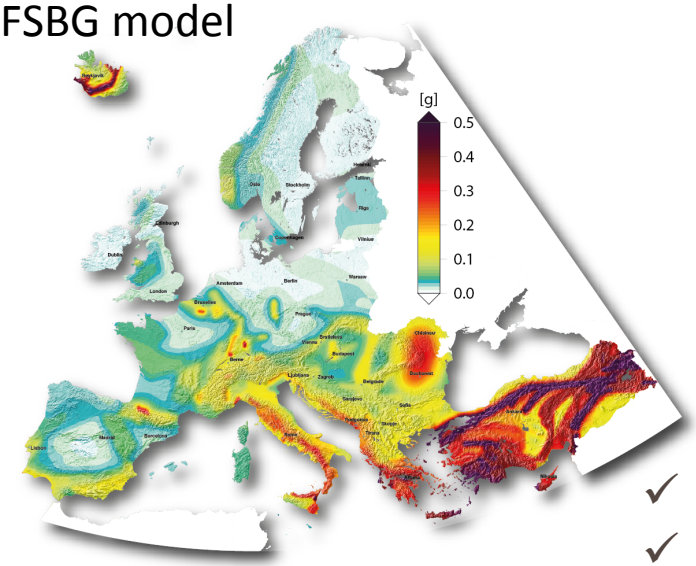

*PGA 475 yr*

# SHARE hazard

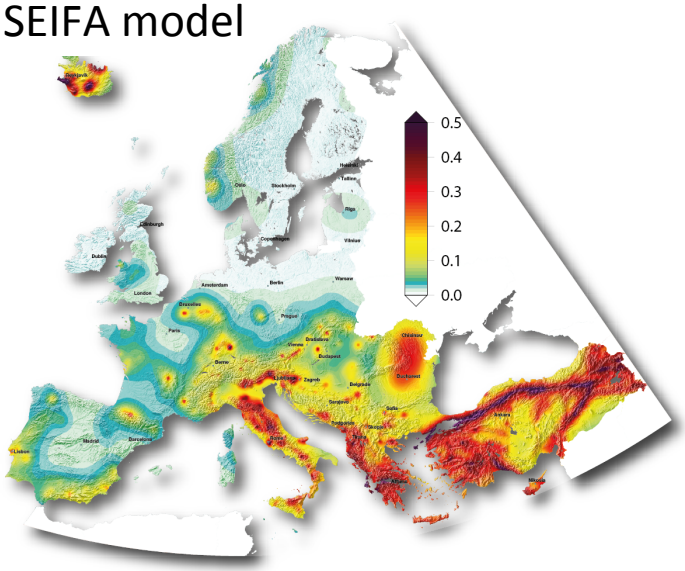
AS model



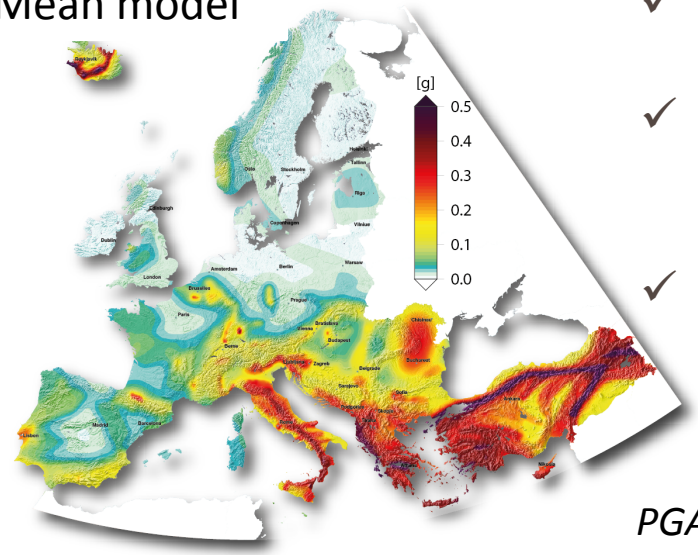

FSBG model




SEIFA model




Mean model

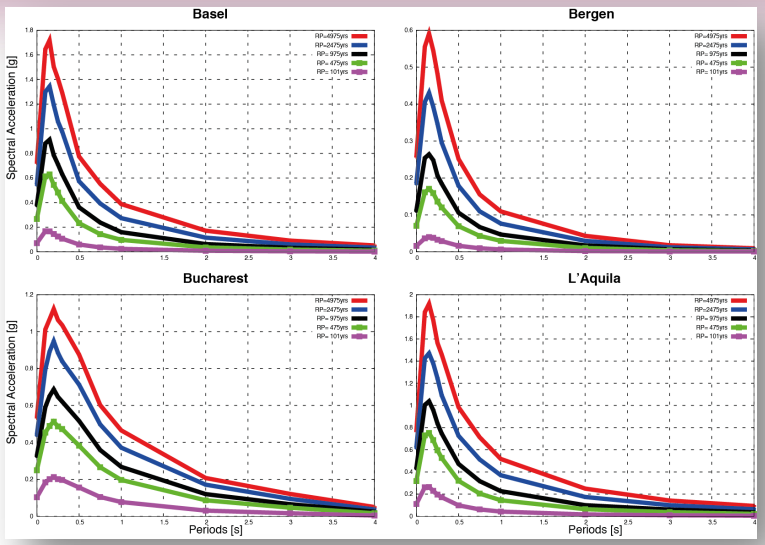


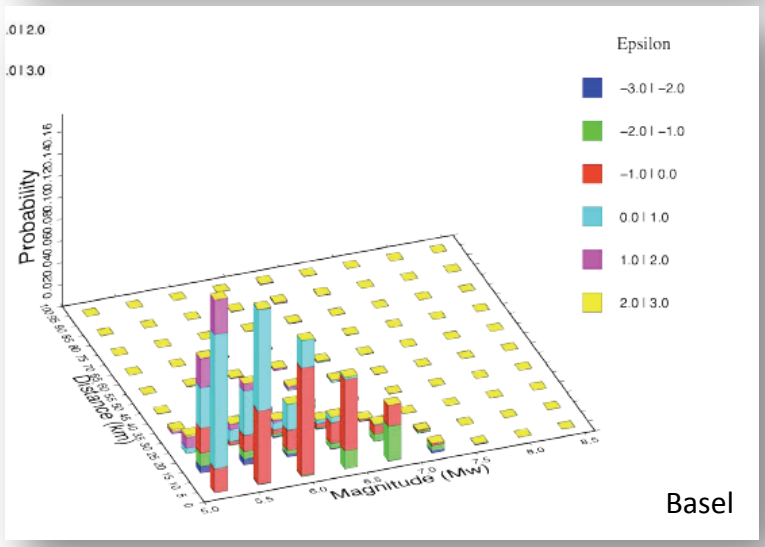

- ✓ 25-5’000 yr
- ✓ PGA, PGV, PGD, SA 0.1-10 sec
- ✓ Uncertainty maps
- ✓ Variable weights for different return periods
- ✓ Over 300 maps

*PGA 475 yr*

# SHARE hazard

- ✓ Single Site Information
  - Hazard Curves
  - Hazard Spectra
  - Uniform Hazard Spectra
  - Disaggregation
- ✓ 120,000 sites on land across Europe



Basel

**Online Access at: www.efehr.org**

# GEM's response to seismic hazard debate

SSA Publications: SRL

OPINION

*September/October 2011*

**Bad Assumptions or Bad Luck: Why Earthquake Hazard Maps Need Objective Testing**

Seth Stein, Robert Geller, and Mian Liu

SSA Publications: SRL

OPINION

*November/December 2012*

**Characteristic Earthquake Model, 1884–2011, R.I.P.**

Yan Y. Kagan, David D. Jackson, and Robert J. Geller

SSA Publications: SRL

OPINION

*March/April 2012*

**Earthquake Hazard Maps and Objective Testing: The Hazard Mapper's Point of View**

Mark W. Stirling

SSA Publications: SRL

*September/October 2012*

***Have Recent Earthquakes Exposed Flaws in or Misunderstandings of Probabilistic Seismic Hazard Analysis?***

**by Thomas C. Hanks, Gregory C. Beroza, and Shinji Toda**

Contents lists available at SciVerse ScienceDirect

Tectonophysics 2012

journal homepage: www.elsevier.com/locate/tecto

Review Article

Why earthquake hazard maps often fail and what to do about it

Seth Stein [a,*], Robert J. Geller [b], Mian Liu [c]

## Conclusions

- ✓ GEM established new standards in SHA (probabilistic and scenario-based) as well as in the assessment of vulnerability, risk and socio-economic consequences
- ✓ GEM global and regional hazard studies combining multiple information (seismic history, geodesy, geology) provide an integrated view of seismic hazards and improved understanding of the earthquake process
- ✓ The new SHA standards and results are the benchmark for global, regional as well as site-specific studies
- ✓ IASPEI is very much involved in GEM and will continue its association in the future

GEM