Earthquake Resilience:
Lessons from the 2016 Central Italy Earthquake Sequence

Geographic and temporal distribution of
ground motions and damage

Paolo Zimmaro
University of California, Los Angeles
Acknowledgements

Jonathan P. Stewart (UCLA) – GEER Team Leader
Giuseppe Lanzo (University of Rome – La Sapienza)
Maria Giovanna Durante (UCLA)
Kevin W. Franke (BYU)
Robert E. Kayen (USGS)
Bret Lingwall (South Dakota School of Mines)
Giuseppe Scasserra (UniMol)
Luigi Di Sarno (University of Sannio)
Anastasios Sextos, Raffaele De Risi (University of Bristol)
Stefano Gori, Emanuela Falcucci, Fabrizio Galadini (INGV)

More information available at: http://www.geerassociation.org
Outline

• Tectonic setting in Central Italy
• Observed evidences of surface faulting
• Ground motion analysis and aftershock pattern
• Geographic distribution of damage
• Damage accumulation
Tectonic Setting

Normal faults

Sketch of a normal fault (from USGS.gov)

40% of the total and 64% for $M \geq 5.5$
of the ground motions for normal mechanism in the PEER NGA West-2 empirical database are from Italian earthquakes.
Fault segmentation and 2016 events in Central Italy

24 August 2016  M6.1
26 October 2016  M5.9
30 October 2016  M6.5

GEER Team Deployments:
Following the 24 August event:
29 August – Mid-September

Following the October events:
Mid-November – 12 December

From GEER (2016), Zimmaro and Stewart eds.
Mt. Vettore-Mt. Bove fault system

Images courtesy of S. Gori and E. Falcucci
Mt. Vettore-Mt. Bove fault system
Observed evidences of surface faulting

After August event
20-25 cm

After October events
More than 1m

Images courtesy of S. Gori and E. Falcucci
2016-2017 earthquakes sequence: Aftershocks pattern

2016-2017 earthquake sequence

M6.1 Umbria-Marche 1997 event

M6.3 L’Aquila 2009 event
Ground motion spatial distribution

From Zimmaro et al. (201x) – EQS, Under review
Spatial distribution of damage

1 – Accumoli
2 – Amatrice
3 – Visso
4 – Norcia

From Sextos et al. (201x) – EQS, Under review

From GEER (2016, 2017), Zimmaro and Stewart eds.
Reconnaissance approach

**Drone-based observations**

**3D Models**
Incremental damage: Accumoli

Accumoli post 24 August 2016

Accumoli post 30 October 2016
Incremental damage: Accumoli

Accumoli post 24 August 2016

Accumoli post 30 October 2016

From GEER (2017), Zimmaro and Stewart eds.
Incremental damage: Amatrice

From GEER (2017), Zimmaro and Stewart eds.
Incremental damage: Norcia

From GEER (2017), Zimmaro and Stewart eds.
Incremental damage: Norcia

Norcia post 24 August 2016

Norcia post 30 October 2016

From GEER (2017), Zimmaro and Stewart eds.
Norcia: Observed damages vs Damage proxy maps

From Sextos et al. (201x) – EQS, Under review
Closing remarks

- 2016-2017 earthquake sequence with several $M > 5.5$ events
- Mt. Vettore-Mt. Bove fault system surface rupture
- Strong ground motions in a large area along the Apennines
- Damage accumulation during the whole earthquake sequence
- Effectiveness of multi-scale reconnaissance approach
Thank you!

Engineering Reconnaissance Following the October 2016 Central Italy Earthquakes
Version 2
GEER Team Leaders: Jonathan P. Stewart and Giuseppe Lanzo

Report Editors:
Pablo Zimmaro and Jonathan P. Stewart

DOI: 10.18118/G6HS39
Geotechnical Extreme Events Reconnaissance Association
Report No. GEER-050D
8 May 2017

http://geerassociation.org