Shakemaps of the L'Aquila main shock

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ABSTRACT:

This work addresses the determination of the shakemap of the l'Aquila, M6.3 April 6, 2009, main shock. Since 2006 and as part of national projects funded by the Italian Civil Protection and by the EU SAFER project, INGV has been determining shakemaps for M3.0+ using the USGS-ShakeMap software package and a fully automatic procedure, based on manually revised location and magnitude. This work summarizes how the shakemaps of the main shocks have been obtained. Focus of the presentation is on the importance that the data and the extent of the finite fault have in the determination of faithful ground motion maps.

For the L'Aquila main shock, we have found that the data alone are not sufficient to replicate the observed ground motion in parts of the strongly affected areas. In particular, since the station coverage toward the SE where the earthquake rupture propagated is scantier, prompt availability of a rupture fault model would have been important to better describe the level of strong ground motion throughout the affected area. We present an overview of the performance of the INGV real time system during the L'Aquila main shock - the first time that INGV provides real time information to Civil Protection during a seismic crisis. Finally, we show a comparison between the intensities determined from the strong ground motion and those obtained from the macroseismic survey.
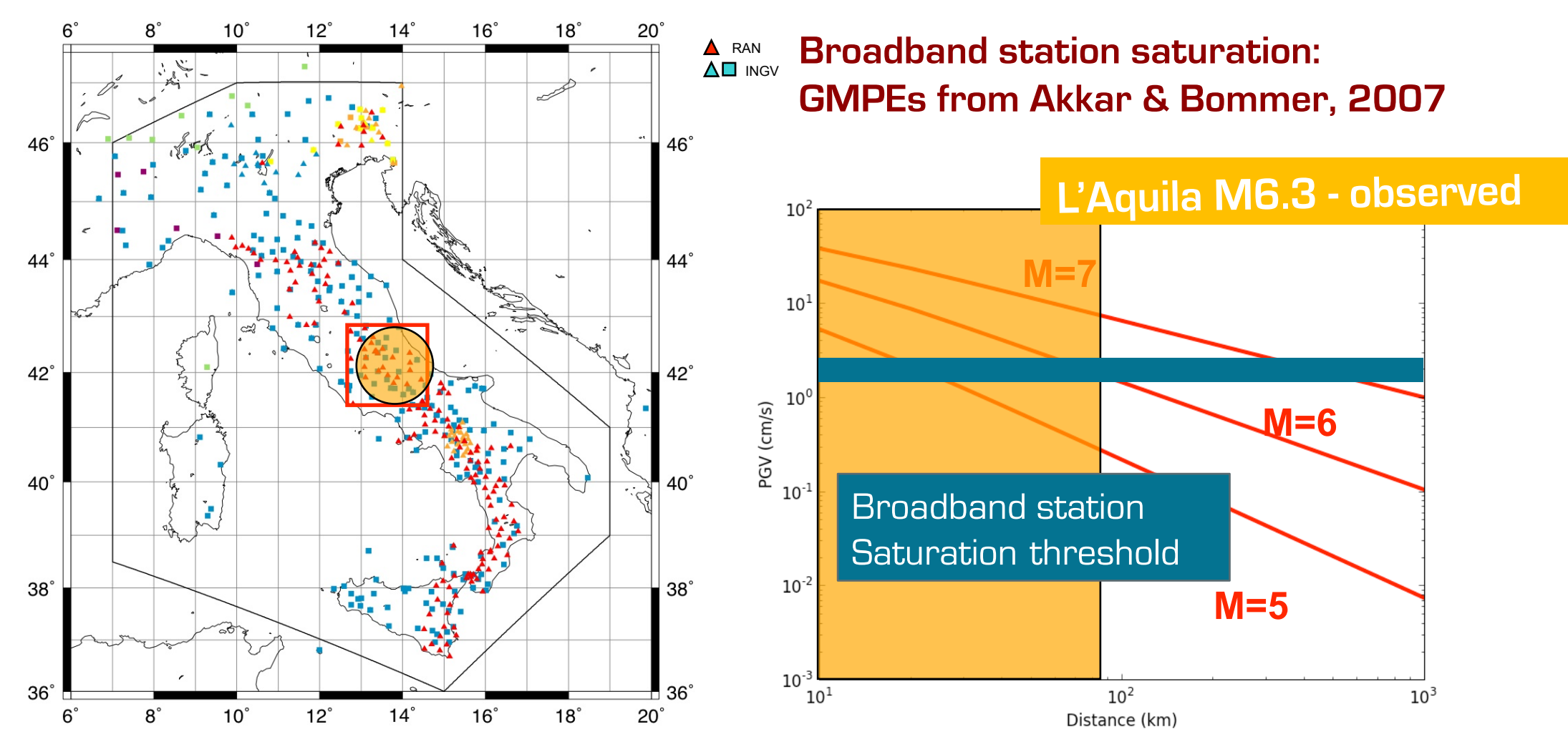
How it went...

- **Automatic Location: (03:37 local time – 4'-5')**
  2009/04/06 01:32:39.47 INGV automatic regional location

origin time	lat	lon	dep
01:32:39.47	42.33	13.34	1.4

- **Manual Location:**
  Available after ~15' (same epicenter but Z=9 km)
- **Magnitude:**
  ML=5.9 (03:37 local time - automatic - 4'-5')
  ML=5.8 after manual revision (~15')
  Mw=6.3 became available after ~2 hours (from QRCMT)
  First ShakeMaps: available within 30'
- **But...**

INGV ShakeMap data

- **Broadband data from INGV stations**
  Saturated for Δ<80-90 km
- **Strong motion data from 6 channels INGV stations (~60 through Italy and mainly from satellite stations)**
  Did not become available because of satellite band saturation
- **AQU (MedNet) strong motion available very shortly**
- **Data uploaded on ftp server from other networks and network operators**
  none available in the Aquila area
- **RAN network (i.e., Civil Protection strong motion network)**
  Most stations available after 7 hours upon request

Italian strong motion and broadband data

▲ RAN ▲ INGV

Broadband station saturation:
GMPEs from Akkar & Bommer, 2007

L'Aquila M6.3 - observed

M=7

Broadband station Saturation threshold

M=6

M=5

Implementation of ShakeMap at INGV:

- Publishing maps for M≥ 3.0 since 2006
  http://earthquake.rm.ingv.it/shakemap/shake/archive
- Fully automated maps generated from:
  Manually revised location and magnitude for map generation (available within 30')
  Automatic EarthWorm location and magnitude (currently suspended)
- Publication of M>4.5 requires "nulla osta" from Italian Civil Protection
  (changed policy after ~10 days in the sequence)

Ground Motion Predictive Relationships

Regionalization of the attenuation relations for M <5.5 events (Malagnini et al.).

For M ≥ 5.5 events the relations of Akkar and Bommer 2007 are used.

Colors in PGA and PGV match the zones
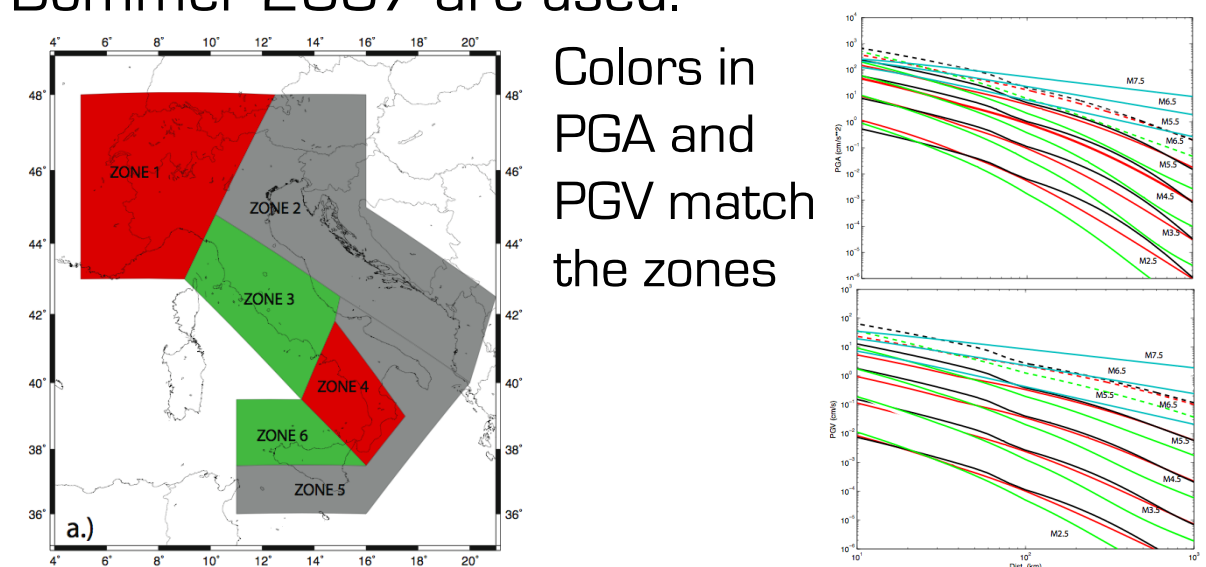
Site Corrections

Map based on geology and shear wave velocity in the top 30 meters.
The geology units is binned into five classes, according to EuroCode8.

To classify, lithological and age criteria has been used.

First manually revised, intensity ShakeMaps (only INGV-BB ~2:00 a.m. GMT)

Manually revised, intensity ShakeMaps (INGV-BB+RAN ~11:00 a.m. GMT)

Final manually revised, intensity ShakeMaps (all data, finite fault -> a few days later)

Differences between the Final ShakeMap (INGV+RAN data and finite fault) and the First ShakeMap (INGV only data)

INTENSITY

PGV

PGA

Comparison with the Macroseimic Field

Data courtesy of Quest.

How it can go...

- **Automatic Location:**
  ~ 20-40 seconds 03:33a.m. local time
- **Magnitude**
  Ml=5.9 (~3'-4')
  Mwp=6.3 (~10'-15')
  Mw=6.1 (AutoTDMT ~30')
  Mw=6.3 (QRCMT, ~1 hour)
- **First ShakeMaps** from automatic location with
  all data but no fault can be available within 5-6 minutes
- **ShakeMaps including the finite fault** can be available
  as soon as the first moment tensor is available together
  with tectonic knowledge on the area

How close we are...

- **System Standardization:**
  New modules must be easily inserted in the standard processing systems
- **Location:**
  Really close
- **Magnitude**
  Progressive magnitude assignment
  ML - Mwp/Mwpd - Mw
  Mw authoritative magnitude
- **Finite fault determination**
- **Establish continuous real-time strong motion data exchange**
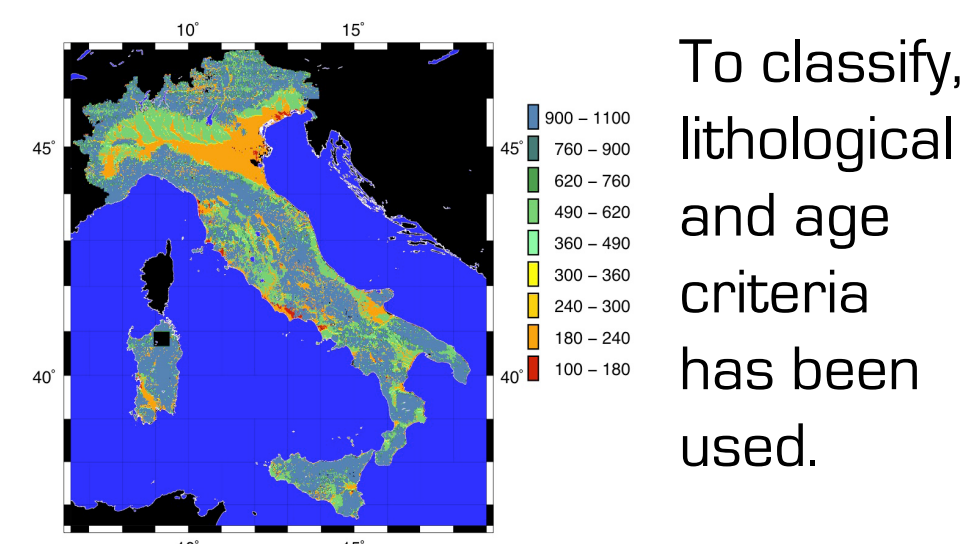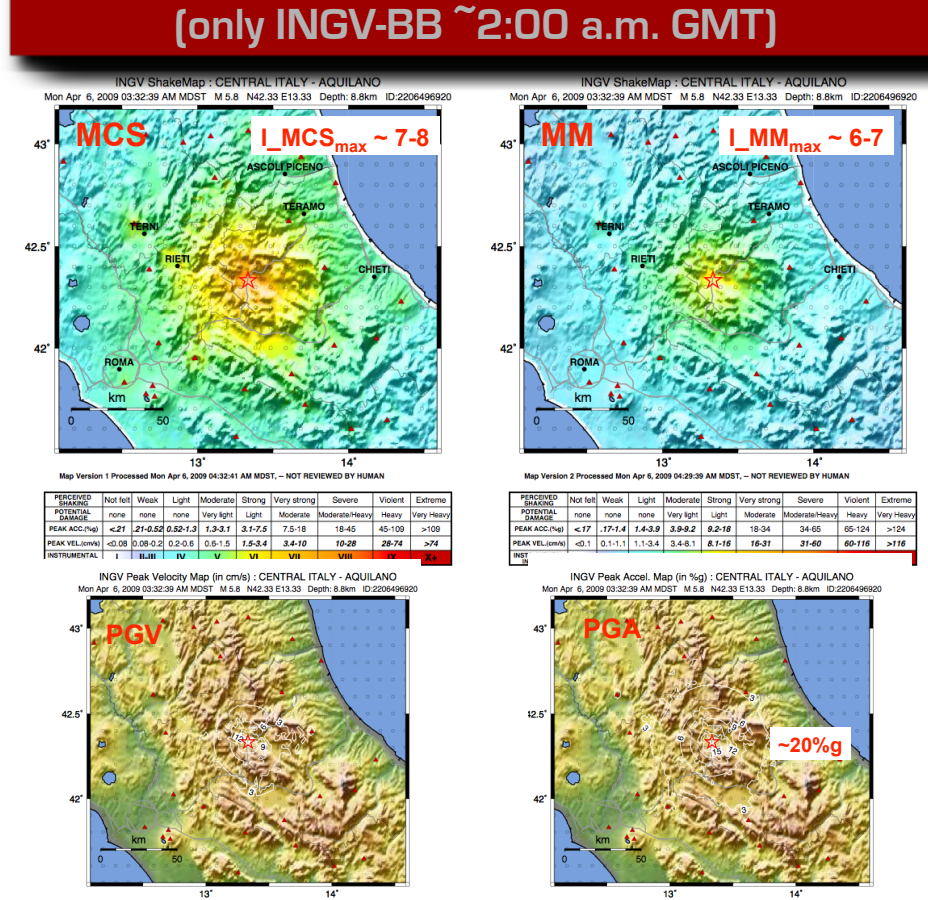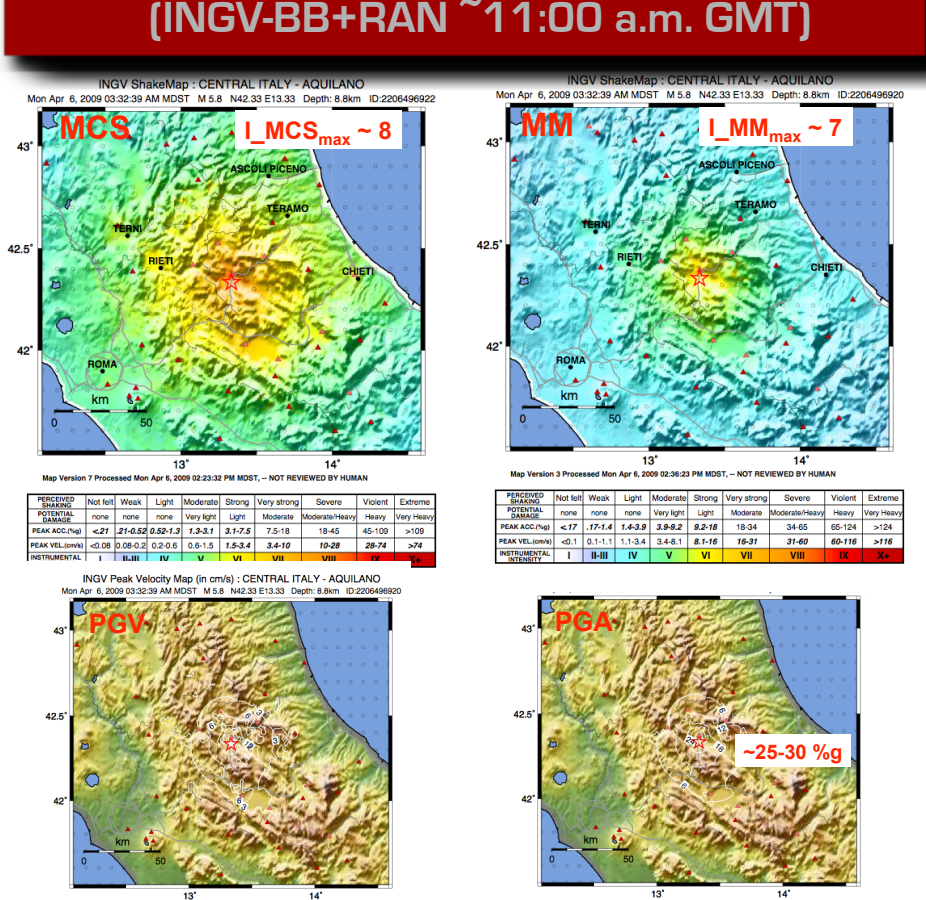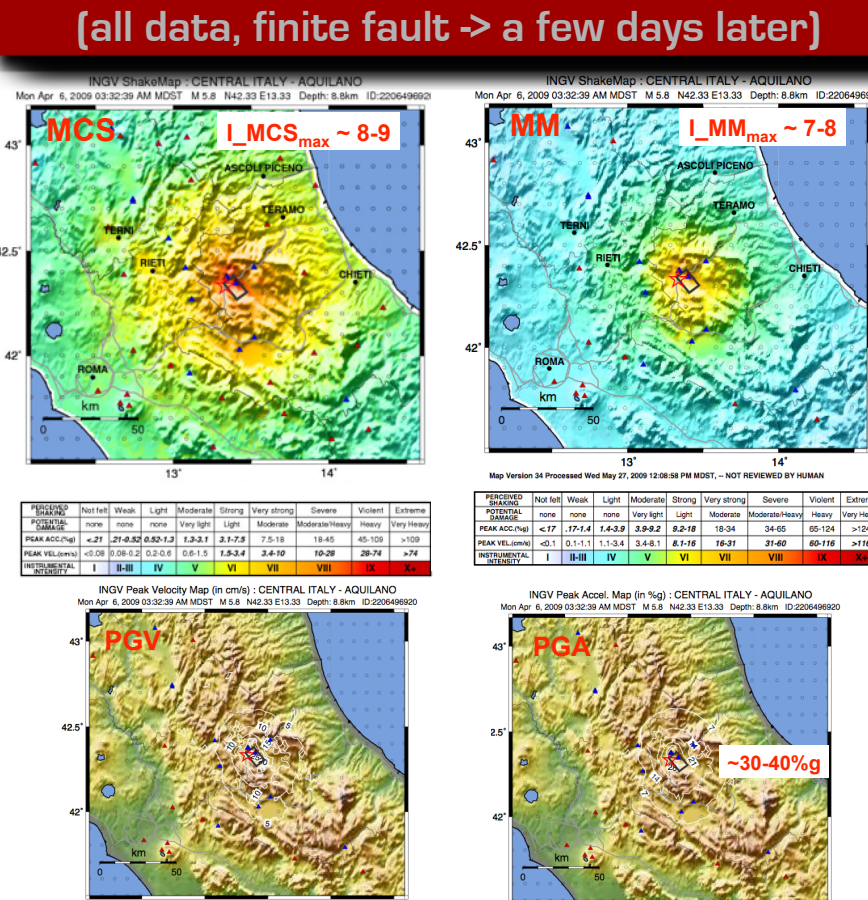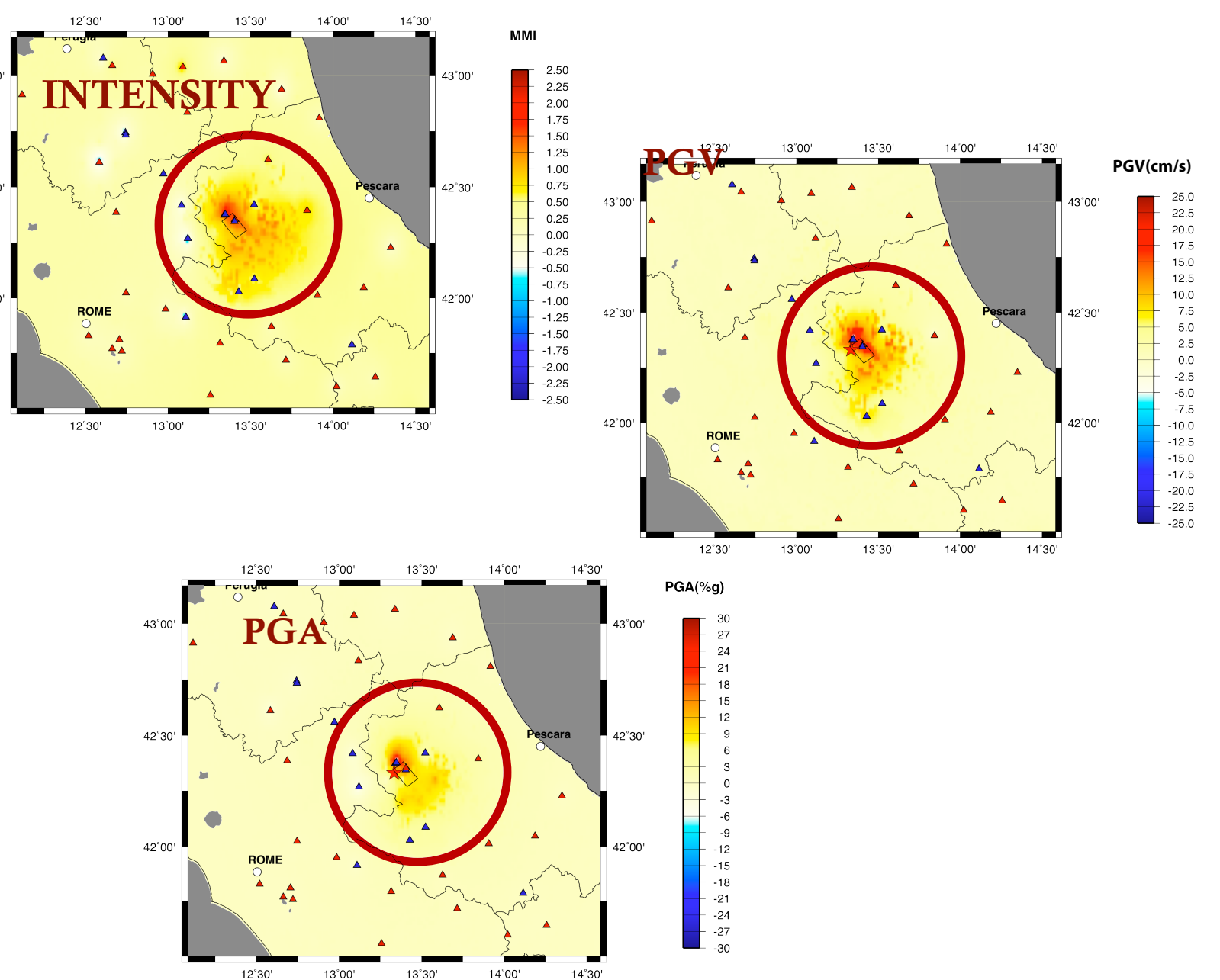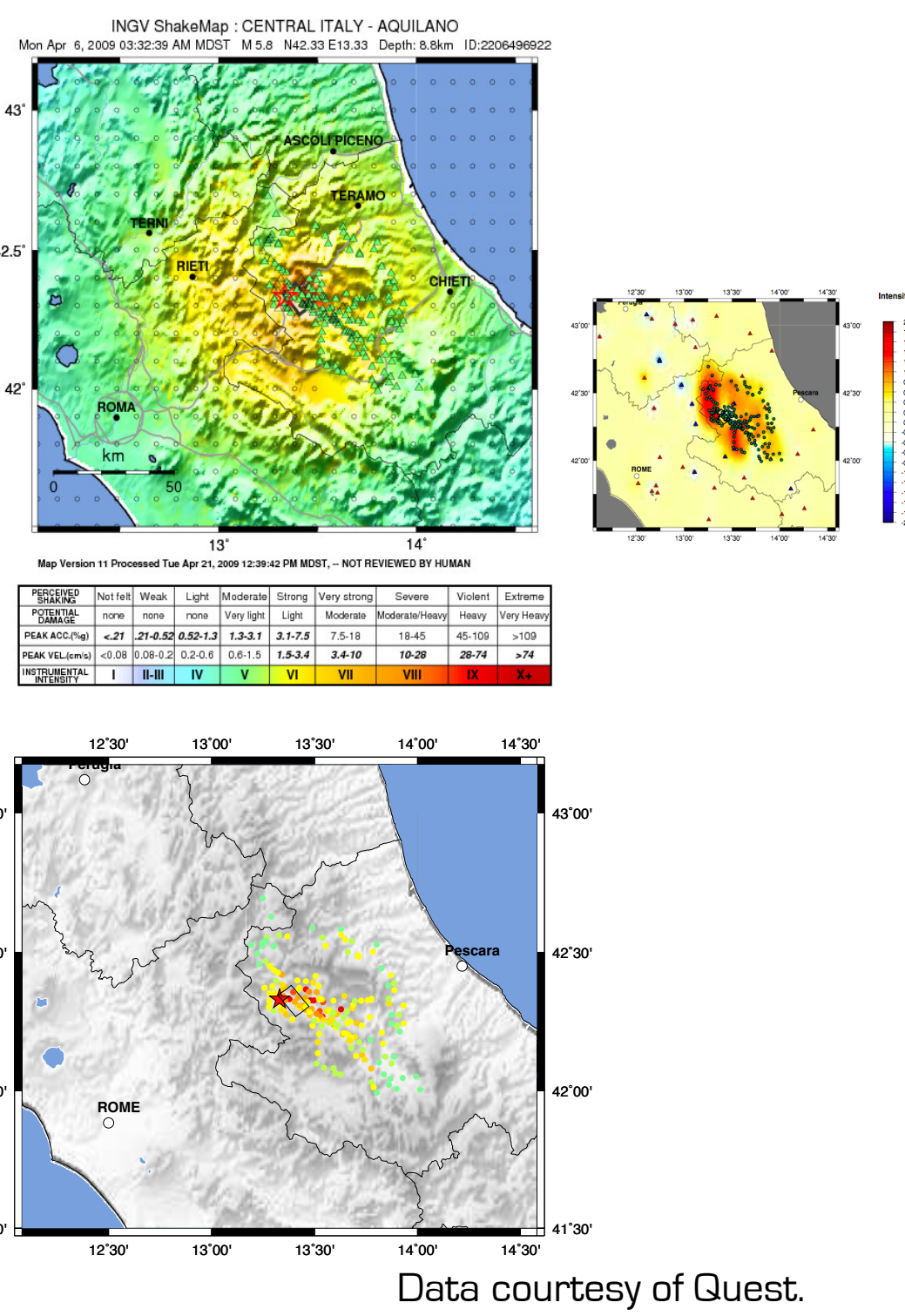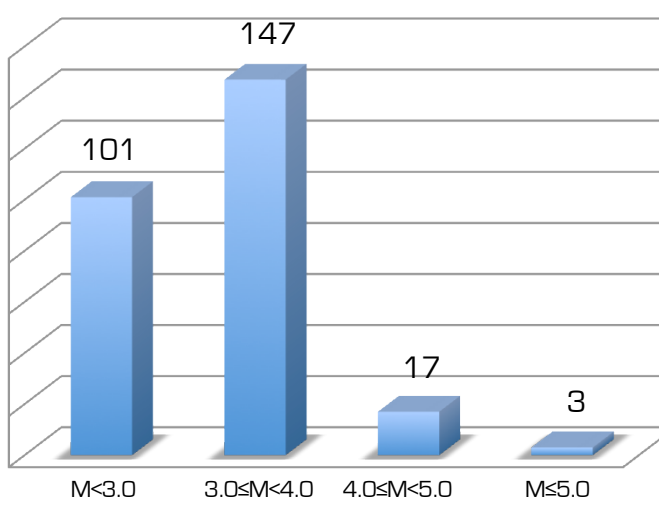 The L'Aquila eq did teach us a lot...

- **Re-establish ShakeMap generation based on automatic processing**
  Easy to do since EarthWorm has already the relevant module
- **When is a ShakeMap really needed for decision making (1', 5', 10' or 30')?**
  In our experience civil protection agencies will "use" the info not earlier than 10' and most likely ~30'
- **The ShakeMap procedure should be progressive/evolutionary**
  Updated progressively as more info/data becomes available

OVERALL:

268 total ShakeMaps published from April 6, 2009 to October 12, 2009 in the Aquilano area

101	147	17	3
M<3.0	3.0≤M<4.0	4.0≤M<5.0	M≥5.0